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The Warm Water Tank Retting of Linen Flax.

*By A. M. Munro, M.A.**

Summary.

During the past twelve months, the author has investigated a few of the many problems encountered during the warm water tank retting of flax. In the article that follows he describes an experimental retting plant and some of the conclusions reached after carrying out a large number of small scale tests. An account is also furnished of the usual physical tests applied to flax straw in order to determine the technical "end point" of the ret, together with a description of three new tests for the completion of the ret which have been worked out in the laboratory.

Tank retting has now been successfully established at Colac, Victoria, by Flax Fibres Pty. Ltd., and the produce of about 1,000 acres of flax is being dealt with at the present time. In the coming year, at least 2,000 acres are to be planted in this district, and a rapid expansion of the industry in the near future is anticipated. The lay out of a tank rettery, based on practical experience, is described.

1. Introduction.

In a report that was prepared by the Imperial Institute and published in this Journal in August, 1938 (Vol. 11, p. 239), a short description of flax retting is given, and it is pointed out that warm water tank retting is now displacing other methods of preparing flax fibre from the straw. In Courtrai, Belgium, for example, where the world's finest fibre is produced, a complete change over from retting in the famous Lys River, the so-called "golden river," has occurred, and practically all retting is now carried out in tank retteries established on its banks and elsewhere throughout the country.

During the past 40 or 50 years, sporadic attempts have been made in Victoria to grow flax and prepare the fibre on a commercial scale by dew retting, but, owing to the variable quality of the fibre obtained by this method, no permanent success was attained and the reputation of Australian-grown flax on the overseas markets was damaged. Dew retting, possible in Ireland, Russia, and on the Continent, proved totally unsuitable for the Australian climate. It has been demonstrated for many years, and noticeably so during the past two, that flax can be grown in many districts of Victoria and South Australia with great

* An investigator attached to the Division of Forest Products.

success during years of normal rainfall, and that a high yield of fibre of the highest quality results, provided that correct methods of processing are employed. Warm water tank retting is the key to the problem of separating high grade flax fibre from the straw.

Tank retting is a new departure from the older methods of flax treatment and, little precise and scientific information being available, it necessarily follows that experimental work must be carried out both in the laboratory and at the factory before the process becomes reasonably uniform and amenable to accurate control. A beginning has now been made with both phases of this work, and one Victorian factory is now successfully treating many tons of flax straw monthly in tanks, and aims at greatly increased production in the near future.

Tank retting is a new departure from the older methods of flax is in the warm water, many classes of bacteria, originally present on the stalks and roots of the plant, develop and make a selective attack on the straw. In the first place they devour the cementing substances, loosely classed as pectins, and partially free the bast fibres of the flax straw from the surrounding tissue, while at the same time freeing to a certain extent the fibres from each other. Attack may, presumably, go a step further and loosen the fibrils or cells composing the fibre itself. Clearly the tank ret is a complex process, difficult to control, and one in which the end point, or stage at which the straw must be removed in order to secure the best possible fibre, can only be determined by experience aided by the few scientific tests which are at present available. On the exact degree of this bacterial attack during retting, the commercial value of the fibre will depend. It is doubtful, too, whether tank retting can ever become standardized in the sense that flax straw may receive a certain fixed treatment, with regard to time, temperature, and dilution. Owing to the raw material differing in its age, state of dryness, manuring treatment, amount of bacteria on the stalk or roots, and in many other ways, it requires special treatment to yield the best fibre. A rettery, therefore, cannot be run to a strict time table with regard to different batches of straw, if the greatest success is to be secured.

2. A Modern Tank Rettery.

The following is a description of the type of factory or rettery considered suitable for the treatment of flax in this country. The retting pits themselves may be built of concrete of sufficient strength to withstand the weight of about 30,000 gallons of water; a suitable size is:—length 32 feet, width 25 feet, depth 7 ft. 6 in. Such a pit or tank will hold from 8 to 9 tons of straw, together with about 27,000 gallons of water, when filled to a sufficient height to cover the straw. The pits must be fitted with reinforced concrete tops or lids, with an opening large enough to gain access to the pit and to insert or remove the sheaves of straw. If these tanks are set in the ground they will not, in the Australian climate, need special heat-insulation, but, if exposed, should be lagged in some way. In the colder districts of Europe, retting tanks are often insulated with cork placed between two layers of concrete. Lids are necessary to reduce surface cooling during the night or cold weather. At the bottom of the tank is a wooden grid, on which

the straw rests, placed at a distance of 12 to 18 inches above the bottom. Under this grid sets of cast iron heating coils, through which hot water or low-pressure steam can be passed, are fitted. These coils are used to maintain the temperature of the ret. Round the sides of the tank, at the bottom and under the grid, a concrete or stoneware pipe runs; from this pipe project a number of smaller copper outlet pipes or jets, which are used to add fresh water to the ret. The size of these is immaterial provided that they will allow a few thousand gallons of water to be run in in the course of an hour or so. The floor of the tank slopes from all sides to the centre, where an outlet pipe, covered by a grid, is placed for removal of the contents of the pit. From the bottom of the pit rise four equally spaced concrete pillars, about 12 inches in diameter, carrying slots in which beams can be fixed. During the early stages of the ret, the straw tends to float to the surface, exerting so strong an upwards thrust that it must be held in place by means of stout wooden beams slipped into a groove at the upper edge of the pit and into the slots in the concrete pillars. The sheaves are best held down in this way and not allowed to rise against the lid of the pit where they would probably emerge from the retting liquor and become exposed to the air. Moreover, rets appear to proceed more smoothly when an air space is maintained above the surface of the liquor, facilitating the escape of the large quantities of gas, mainly hydrogen, which are evolved at certain stages of the process.

For accurate control of temperatures, the tanks should be fitted with valves on the inlet to the heating coils and to the hot water supply pipes; in the writer's opinion, thermostatic control, operated through electrical contact thermometers placed in the centre of the ret, would be a worth-while addition. Recording thermometers in each pit are a necessity as a check on hand control during the six or seven days' continuous operation. Thermometers should also be placed at the various inlet and outlet valves.

For the supply of hot water a large boiler, fired with the "shives" or woody particles beaten off the retted straw during "scutching," is needed, together with a 50,000 to 100,000 gallon hot water storage tank.

The furnace should have a tall stack in order to minimize the danger of sparks escaping into the very inflammable dust present in the neighbourhood of the scutching machines, or into the stacks of straw, and in some cases a water spray operating inside the base of the stack helps to reduce fire risk. In a well-designed rettery, the scutching sheds are near the furnaces, and the shives, as they escape from under the enclosed scutching machine, may be blown directly into the furnace. Wherever possible in the layout of the rettery, gravity is made use of to facilitate the flow of water and the handling of the straw. Labour costs are high in the flax industry even in countries where wages are low; they become increasingly so in Australia, so that, for the successful development of the industry here, mechanical labour-saving devices must be introduced for such operations as building the stacks of straw, moving the straw to the deseeding plant, loading and unloading the retting pits, carrying the wet straw to and through the drying tunnels, and transferring it from the driers to the scutching machines. In short, the industry must eradicate the age-old habit of throwing sheaves of straw about by hand at every stage of the

manufacture. The economical production of fibre centres round the retting tanks, and the plant should be arranged in such a manner that all the operations, stacking and unstacking, deseeding, loading, unloading, drying, and scutching, can be carried out in proper order and without any unnecessary handling of the sheaves.

3. Retting.

Straw from the deseeding machine is tied, either by hand or machine, into bundles which are sent on a conveyor to the retting pits, where they are loaded vertically in two layers, the bottom one, root end to the floor of the pit, and the upper layer with the root end resting on the seed end of the lower sheaves. These sheaves may be packed fairly tightly. Beams are fixed over the upper layer to prevent the straw from rising. The pit is then filled with water at a temperature in the neighbourhood of 25°C. for the rinse or preliminary wash. Various retting procedures are followed. In each case the wash water is run off after about ten to seventeen hours. Fresh water, at a temperature varying in different rets from 30°C. to 34°C. is added, and the ret is allowed to proceed for six or seven days. At different times during the process the liquors are diluted; that is to say, a portion is removed and replaced with fresh water. This dilution hastens the ret and produces a better colour in the fibre than if the straw were allowed to ret continuously in a strong liquor. This class of ret, where no oxygen is present owing to the fact that the liquors remain practically undisturbed, is termed an anaerobic ret and produces special types of bacteria during the various stages of the process.

Determination of the End Point.

The following physical tests can be applied to the straw in order to determine its degree of ret:—

1. *The Loose Core Test.*—A straw is broken in the middle, and the fibres are loosened and freed from the core. About 6 inches away from this break, the same procedure is followed. If the straw is retted the fibres can be drawn off the straw without any resistance in the form of a compact sheath. When the straw is only partly retted, the fibres and cortex can only be pulled away from the core in a continuous ribbon which offers some resistance.

2. *The Leaf Scar Test.*—When the ribbon of fibres is pulled steadily away from the core of a nearly completely retted straw, it offers no resistance until a node or scar is encountered at a point where a leaf grew. There is then a slight drag, and the degree of ret can be judged by an experienced operator from the extent of the resistance.

3. *Epidermis Test.*—A ribbon of fibres from a piece of straw is shaken in water. If retting is complete, the fine fibres separate easily from each other and glisten in the water in a characteristic manner.

4. *Core Test.*—Bent between the fingers, the core snaps sharply with a clean break when retting is complete. If incomplete the straw bends without breaking.

Three methods have also been worked out in our laboratory for determining the end point of a ret by means of the acidity of the retting liquor at different stages of the ret.

The first two depend on the measurement of the pH value of the liquors by means of a Cambridge pH meter and glass electrode. Owing to the presence of organic buffering substances in the liquors, the direct determination of the pH value of the liquor at suitable intervals does not give the necessary information, because, fairly early in the ret, the pH reaches a minimum value with the natural increase in acidity, and it does not change appreciably for several days. On the other hand, if the complete electrometric titration curve for the liquor is determined at 24 hour intervals, a set of curves which can be employed as a guide to the progress of the ret are obtained. Alternatively, the liquors can be titrated at suitable intervals until the pH value is raised to a definite point, which can be chosen from the titration curves, the figures giving an indication of the end point.

The third method depends on titrating the liquors each day with standard alkali, using certain precautions. The acidity is found to reach a maximum value near the completion of the process. These three methods of investigation, when taken in conjunction with physical tests applied to the straw, give a valuable aid in determining the technical end point of the ret, or point at which the straw should be removed in order to give the highest yield of best quality fibre obtainable.

Referring again to the physical tests described above, the actual estimation of the completion of a ret is difficult and needs much experience in applying the test. It has also to be remembered that the ret may be carried to different stages according to the class of fibre required. Advanced retting gives a very soft fibre, suitable for linen manufacture but somewhat lacking in tensile strength, while at the same time the yield of long fibre decreases and the amount of tow increases. A short retting time would give a higher yield of strong but harsher and coarser fibre.

A totally different kind of ret to the one already described is that patented by the Linen Research Association under the title of the "Duplex" ret. In this system two tanks, A and B, are employed. Straw is placed in A and rinsed with water at 30°C. for four or five hours. This is then run out and fresh water at 30°C. is added, and the straw allowed to ret for three days at 30°C. At the end of this period, the liquor is run off and the tank filled with cold water at, say, 20°C. The straw is allowed to soak in this cold water for four hours, the so-called "rest" period. Meanwhile, tank B is charged with straw and washed for five hours at 30°C. The wash water is run off from both, and the tanks are filled with water at 30°C. and connected by a pipe and circulating pump. For the next three days the water circulates between both tanks, passing over the partly retted and the new straw and carrying bacteria to the latter. At the end of this time the straw in tank A has had six days and is retted. It is removed, fresh straw put in, and the procedure repeated. One lot of straw is always three days ahead of the other and the process is a continuous one. This system has been thoroughly tested in the laboratory and the resulting fibre found to be of excellent quality. Owing to the constant agitation of the retting liquor, this ret develops oxygen-using bacteria and becomes partly aerobic.

4. Laboratory Investigations.

The experimental retting plant used in our Australian investigations consisted of two sets of galvanized iron tanks, measuring 4 feet by 1 foot by 1 ft. 6 in. and 2 feet by 1 foot by 1 foot, respectively, the larger tanks taking full length straw without trimming. These tanks were well coated inside and out with bituminous paint, in order to prevent corrosion and the contamination of the liquors with iron salts, iron in a retting liquor causing serious discoloration of the fibre. The retting tanks were placed in outer, water filled, thermostat tanks, in which the temperature could be kept constant by means of immersion heaters operated through electric contact thermometers and relays. Mechanically driven stirrers were fitted in the thermostats, and the latter were heat-insulated on the outside and provided with lids.

Straw could be retted in this plant under very exact temperature control and at exact states of dilution. The larger thermostat was provided with a silent steam injector for raising the temperature of the large volume of water quickly with steam, final adjustments being made with the electric immersion heater. Warm water was also available from a nearby steam and water mixing valve. The contact thermometers used, could, by means of a magnet, be set at any temperature without removal—a great advantage when working on an ascending scale of temperature. Sponge rubber mountings prevented these contact thermometers from being shaken out of adjustment by vibration from the motor driving the stirrers. Batches of straw retted in these tanks were dried on wire-netting trays placed on the roof of the building, and then scutched on a modern drum scutching machine in order to secure uniform mechanical treatment.

5. Conclusions Reached from a Large Number of Experimental Rets.

(i) *Temperature.*

Temperature is one of the most important factors in successful retting. If the straw is washed at the commencement of the ret for a considerable time at too high a temperature, the subsequent retting is retarded, and a dry, harsh type of fibre results. The temperature employed and the time of washing are, of course, interdependent. Washing periods of from 6 to 24 hours, at a temperature in the neighbourhood of 25°C., are satisfactory, but, if the temperature is raised to 30°C. or 33°C., the leaching will be overdone. In the latter case four or five hours would be sufficient. In the case of the actual retting itself, the most widely used temperatures range from 30°C. to 33°C., and it is recommended in Courtrai that the ret temperature should be gradually raised from 30°C. to about 33°C. over a period of several days. A large number of very successful rets have been carried out in Australia at a uniform temperature of 33°C., and it is considered that this rise, often used on a large scale, may be unavoidable on account of the difficulty of raising the temperature of the pit and its contents to the higher temperature in a short time, and may not really be advantageous. Temperatures over about 45°C. to 50°C., brought about sometimes by the too sudden addition of hot water, must be avoided, as they tend to kill the retting bacteria. It has been found that, both on the large and small scale, the temperature of the ret must not be allowed to drop at any time. If it does so, the ret will

not always recover when the temperature is again raised; it appears to have been killed in some way. A bad smell develops, quite different from the normal retting odour, and the straw will not ret completely but gives a harsh under-retted fibre. A temporary small rise in temperature appears to be far less serious. It appears then that one of the most important things when retting is to maintain a steady and correct temperature, particularly avoiding a drop in temperature at any time.

(ii) *Ratio of Straw to Water and the Dilution of the Ret.*

A ratio of straw to water of 1 to 20 parts by weight is recommended by some workers, but it has been found that in practice, 1 to 12 or less can be used and is more economical. During the first 24 hours of the ret, a 10 per cent. dilution of the liquor with fresh water is usual, and if this is omitted the fibre tends to become a bad colour, showing a dirty grey rather than a golden shade. At the same time, it has actually been found that the ret is retarded if insufficient dilution is given. Within the next 24 hours, a still further addition of 10 per cent. of water can be made with advantage. If warm water is continually run into the ret in the place of separate additions for the first two days, it is essential (i) that too much water should not be used, and (ii) that it should be added at the correct temperature. Over dilution leads to a slowing of the ret and the production of a harsh, badly-stained fibre, without gloss and weight. Several types of ret, in which very large dilutions are employed, are described in the literature of flax fibre production, but we have not found these methods very successful, at any rate on a small scale, and do not recommend them.

(iii) *Quality of the Water Used for Retting.*

Water plays an important role in all tank retting processes, and a comparatively large quantity is required, the flax grown on 1,000 acres, for example, requiring no less than 30,000,000 gallons during the year for treatment. It has always been insisted in the past that the water for tank retting should be soft and free from dissolved mineral matter, but a successful rettery has been established at Colac, Victoria, which makes use of water drawn from Colac Lake. This water is very highly mineralized, containing about 5,000 parts per million of dissolved mineral matter and a hardness of about 55° (parts of calcium carbonate per 100,000 of water). The fibre produced is of excellent quality, and thus it appears that the softness of the retting water is not so important as generally believed. Another interesting departure from overseas practice is the cutting of flax straw grown in Victoria with a reaper and binder in place of the pulling machines used abroad. Cut straw rets well and gives a good fibre. The only serious disadvantage in cutting is that, particularly on uneven land, a considerable amount of valuable fibre is left in the stubble. This loss, however, can be minimized by fitting special attachments to the standard machines to facilitate close cutting.

The Effect of Tobacco Licks Used for the Prevention of Trichostrongylosis in Sheep.

*By Hugh McL. Gordon, B.V.Sc.**

1. Introduction.

To the grazier, the administration of an anthelmintic in lick form appears to offer the simplest method of control of worm parasites. For many years numerous drugs have been incorporated in proprietary licks, with the hope that some anthelmintic effects would be manifest. There are several obvious objections to the incorporation in licks of potent anthelmintics, which, it must be remembered, usually possess marked toxic properties when excessive doses are taken. Firstly, the amount of lick taken by different individuals varies enormously, so that some animals are likely to ingest excessive doses, and others only minute amounts. Secondly, the amount of lick taken varies greatly from day to day and from season to season, and it is thus almost impossible to ensure the individual's intake of the drugs incorporated. When animals are hand-fed in feed-lots or stalls, it is a different matter, for in such cases the intake can be controlled. Finally, it has been shown by Boughton and Hardy (1934) in U.S.A. that long-continued intake of licks containing copper sulphate leads to chronic copper poisoning, a condition simulating the so-called toxaemic jaundice of sheep which occurs in parts of Australia.

In South Africa, the use of licks containing about 13 per cent. tobacco leaf was advocated by Veglia (1928) in the control of verminosis in sheep.

Clunies Ross (1932) has shown that consumption of licks containing sodium arsenite and copper sulphate, or copper sulphate alone, had no value in lessening infestation with *Haemonchus contortus* or *Oesophagostomum columbianum*.

Previous unpublished observations at this Laboratory (Clunies Ross and Gordon) indicated that licks containing tobacco dust have no effect on the development of haemonchosis and trichostrongylosis.

The present experiment deals with the trial of a proprietary tobacco lick preparation of allegedly high nicotine content (about 10 per cent.). The preparation also contains other ingredients, the nature of which cannot be stated. This tobacco lick preparation was claimed to be of value in the control of trichostrongylosis. The control of this disease presents so many difficulties, and is of such great importance, that, in spite of previous indications of lack of efficiency of materials administered in lick form, it was felt that a further trial was worth while. By including a group of sheep to be dosed daily with the tobacco preparation, it was hoped to determine with greater certainty whether it possessed anthelmintic properties.

2. Experimental Procedure.

Thirty worm-free sheep (about five to six months old) were divided, on the basis of gains in body weight, into three comparable groups. The sheep were weighed weekly, and were dosed daily with infective

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larvae of *Trichostrongylus* spp. (chiefly *T. colubriformis*). The number administered daily varied from 1,000 to 2,000 larvae. A total of 65,000 larvae was administered to each sheep during the period 18th August, 1938, to 8th October, 1938. Coarse salt was available to all groups, being provided in boxes in the pens occupied by the sheep. The salt was weighed weekly and a fresh supply made available. Group A received no other treatment. Group B received a lick composed of six parts coarse salt and one part of the proprietary preparation containing ground tobacco leaf and other ingredients (this preparation contained about 10 per cent. nicotine). This mixture was available for about ten days before the administration of larvae began. Group C was treated by the daily administration from a spoon of 1 gm. of the proprietary tobacco preparation for each sheep. The suppliers of the preparation recommended a level medical teaspoonful per day per sheep (one year old). This amount was approximately 1 gm. In groups B and C, the drinking water was impregnated with iron sulphate (the exact amount was not determined, the water being just coloured red-brown by agitating in it a bag containing crystals of iron sulphate). This was done on the recommendation of the suppliers of the proprietary tobacco preparation, who stated that iron salts were an advantage for the "reaction of the natural alkaloids."

Egg counts were carried out on the faeces from the 28th day after infection began.

3. Results.

Egg Counts.—These are shown in Tables 1, 2, and 3.

TABLE 1.—GROUP A (CONTROLS)—SALT LICK ONLY.

Eggs per gm. of faeces.

Date.	A 125.	A 184.	A 233.	A 210.	A 247.	A 217.	A 133.	A 223.	A 188.	A 241.
16.9.38	5,600	2,000	3,400	6,800	6,800	4,200	11,800	5,600	4,400	4,200
19.9.38	8,000	3,800	10,400	10,800	23,400	7,600	30,000	3,400	8,800	6,000
23.9.38	..	4,200	7,200	13,000	..	..	35,800	4,200	16,200	8,200
26.9.38	Dead	8,800	5,600	12,000	50,400	8,400	37,400	3,000	6,000	9,600
30.9.38	..	10,600	13,400	16,000	19,200	10,000	18,400	3,000	36,400	9,400
4.10.38	..	11,400	19,400	34,600	9,800	27,600	Dead	..	..	20,000
7.10.38	..	3,800	10,800	32,200	Dead	10,400	..	4,600	27,200	18,200
10.10.38	..	9,800	20,200	34,200	..	15,200	..	5,600	16,000	13,600
14.10.38	..	15,200	20,200	25,400	..	20,400	..	7,400	28,200	11,400
18.10.38	..	11,600	19,400	68,000	..	26,200	..	10,200	24,400	25,800

TABLE 2.—GROUP B—SALT AND TOBACCO LICK.

Eggs per gm. of faeces.

Date.	A 176.	A 198.	A 170.	A 232.	A 246.	A 224.	A 185.	A 240.	A 225.	A 143.
16.9.38	8,800	10,600	1,800	13,200	4,800	5,800	7,200	1,200	6,000	5,200
19.9.38	9,000	54,400	7,000	20,000	10,200	7,000	13,800	24,600	6,000	5,000
23.9.38	21,200	11,400	11,200	16,000	7,600	14,600	13,600	..	8,400	9,400
26.9.38	5,400	Dead	14,000	20,400	8,200	14,000	10,000	48,000	8,600	8,200
30.9.38	Dead	..	16,000	14,800	14,600	15,600	20,800	53,400	8,000	10,200
4.10.38	..	..	21,600	24,600	21,400	24,200	31,200	53,600	26,400	40,800
7.10.38	..	..	7,400	17,400	13,800	12,600	32,400	28,600	14,400	16,200
10.10.38	..	..	40,400	17,000	10,600	16,200	16,600	36,400	6,200	..
14.10.38	..	..	19,600	31,400	11,200	25,800	33,200	Dead	8,600	32,800
18.10.38	..	..	72,800	40,800	26,800	32,800	38,000	..	10,400	36,400
			Died		Died					

TABLE 3.—GROUP C—SALT AS LICK. TOBACCO PREPARATION ADMINISTERED DAILY.

Eggs per gm. of faeces.

Date.	A 137.	A 239.	A 216.	A 177.	A 129.	A 249.	A 141.	A 186.	A 142.	A 131.
16.9.38	9,400	4,600	1,000	600	5,200	1,400	4,000	1,000	8,800	6,800
19.9.38	11,200	3,000	2,600	7,200	8,800	3,800	11,200	1,800	18,600	6,600
23.9.38	8,400	1,800	2,400	5,600	10,400	7,600	7,400	3,200	13,800	5,600
26.9.38	16,800	3,200	6,000	9,800	7,000	6,000	6,200	6,400	7,000	7,600
30.9.38	25,000	5,200	17,000	13,800	13,800	7,000	15,600	8,800	15,000	8,000
4.10.38	19,800	9,200	...	29,800	19,600	6,400	12,600	12,800	21,800	16,800
7.10.38	16,800	9,400	14,000	15,200	13,400	11,800	4,400	14,600	15,800	9,800
10.10.38	21,800	2,200	11,200	13,600	21,800	11,400	12,400	13,200	20,800	12,200
14.10.38	49,600	5,800	Dead	16,000	17,400	..	10,800	17,400	33,600	16,400
18.10.38	40,600 Died	2,000	..	41,800	20,200	11,000 Died	10,200	15,200	18,400	9,400

There is nothing in the egg-count figures to suggest any differences in the degrees of infestation set up in the three groups. The tobacco preparation was evidently ineffective in preventing the development of trichostrongylosis.

4. Post-Mortem Findings.

A number of sheep died in each group. Four of these deaths were associated with an infection of the gall bladder, one was due to intussusception of the small intestine, and the remainder are considered to have been due to trichostrongylosis.

Table 4 shows the results of post-mortem examinations.

TABLE 4.

Group.	Sheep.	Number of *Trichostrongylus* spp. present.	Cause of Death.
A	A 125	11,500	Gall bladder infection
	A 247	18,500	Gall bladder infection
	A 133	10,000	Trichostrongylosis
B	A 176	8,000	Intussusception
	A 198	9,000	Gall bladder infection
	A 170	33,500	Trichostrongylosis
	A 246	42,000	Trichostrongylosis (slight catarrh of gall bladder present)
	A 240	20,400	Gall bladder infection
C	A 137	18,520	Trichostrongylosis (slight catarrh of gall bladder present)
	A 216	16,000	Trichostrongylosis
	A 249	17,500	Trichostrongylosis

It is seen that deaths from trichostrongylosis were: Group A, one sheep; Group B, two sheep; Group C, three sheep. The numbers of worms recovered at post-mortem did not show any very striking group

differences. Two high worm counts were recorded in Group B, but it is not considered that there is any significance in this, it being known that the number of these worms necessary to kill a sheep varies within fairly wide limits depending on such factors as body weight, resistance, nutrition, &c. The cause of the gall bladder infections was not determined, but there was no suggestion that trichostrongylosis was related to the lesions. The lesions varied, in several cases being small rounded ulcers from 1-5 mm. in diameter. In other cases there were diffuse catarrhal changes. The gall bladder of sheep A247 was almost filled with pus.

5. Amounts of Salt and Lick Consumed.

One could not be certain that each individual consumed lick. In Group B, receiving the tobacco preparation in lick form, periodical examination of the sheep's teeth showed them to be discoloured by a blue ingredient in the mixture, and it appeared that all the sheep in this group had consumed some lick. Table 5 shows figures for salt and lick consumption.

TABLE 5.—SALT AND LICK CONSUMPTION.

Week Ending.—	Group A. Salt per Head per Week.	Group B. (Lick = 6 Parts Salt, 1 Part Tobacco Prep.)			Group C. Salt per Head per Week (+ 7 gm. Tobacco Preparation by Mouth per Head per Week).
		Total Lick per Head per Week.	Salt per Head per Week.	Tobacco Prep. per Head per Week.	
	(grammes)	(grammes)	(grammes)	(grammes)	(grammes)
15.8.38 ..	124·5	37·4	32·2	5·2	52·0
22.8.38 ..	68·5	70·6	60·4	10·2	51·0
29.8.38 ..	70·0	72·4	62·1	10·3	82·0
5.9.38 ..	90·5	63·9	54·8	9·1	76·5
12.9.38 ..	62·5	63·0	54·0	9·0	95·0
19.9.38 ..	38·5	34·4	29·5	4·9	36·0
26.9.38 ..	45·5	34·4	29·5	4·9	42·0
4.10.38 ..	47·7	48·0	42·1	5·9	32·0
11.10.38 ..	Not weighed	33·7	28·9	4·8	Not weighed
18.10.38 ..	31·4	37·9	32·6	5·3	38·3
Average ..	64·3	49·5	42·6	6·9	50·4

The salt consumption varied fairly considerably from week to week within groups, and there are fairly marked differences between the groups. In Group A, the salt intake averaged 14 gm. per head per week more than in Group C. The weekly salt intake per head in Group B was 22 gm. less than that of Group A, and 8 gm. less than that of Group C. It appears that admixture of the tobacco preparation depressed salt consumption in Group B. It appears also that daily dosing with the tobacco preparation in Group C may have resulted in lowered salt intake. There was a tendency to a progressive decrease in the amounts consumed in all groups. This was probably associated with depressed appetite and general disturbance of health accompanying the development of trichostrongylosis. The daily intake

of the tobacco preparation by sheep in Group B averaged 0.98 gm. per head per day. The amount administered to sheep in Group C was 1 gm. per head per day.

6. Body Weights.

Change in body weight during the experimental period (18th August, 1938, to 21st October, 1938) are summarized below:

Group A (Control).

5 out of 7 sheep lost from 2 to 4.5 lb.	3 deaths
2 out of 7 sheep gained from 1 to 2.5 lb.	

Group B (Tobacco preparation as lick).

4 out of 5 sheep lost from 1 to 4.5 lb.	5 deaths
1 out of 5 sheep gained 0.5 lb.	

Group C (Tobacco preparation dosed daily).

4 out of 7 sheep lost from 1 to 3 lb.	3 deaths
2 out of 7 sheep were the same weight at the end as at the beginning.	
1 out of 7 sheep gained 1 lb.	

There are no outstanding differences in weight changes between the three groups.

7. Summary.

A tobacco preparation containing about 10 per cent. nicotine, administered to sheep either in the form of a lick, or individually by daily dosing with a spoon, did not check the development of trichostrongylosis. This result confirms previous unpublished observations that tobacco preparations in lick form are of no value in the control of trichostrongylosis.

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The Control of Meat Ants (*Iridomyrmex detectus* Sm.)

*By T. Greaves.**

Summary.

1. A colony of meat ants (*Iridomyrmex detectus*) may occupy a group of nests, and to achieve satisfactory control it is necessary to treat all the nests associated in such a group.

2. Of the various substances tested, carbon bisulphide and granulated calcium cyanide were most effective for treating meat ants' nests, and instructions regarding their use are given. If neither of these substances is obtainable, the use of Paris green or calcium arsenate is recommended.

3. Some observations regarding the attack by meat ants on mound colonies of termites used for the testing of timber samples are recorded.

1. Introduction.

Most of the ants which have become domestic pests in Australia are species which have been accidentally introduced from abroad. Of the indigenous pest species, the best known is the common meat ant (*Iridomyrmex detectus* Sm.). This is probably the most abundant and widely distributed of Australian ants; and as it is well known, and the common name " meat ant " restricted to this one species, a description of the insect is not required.

Meat ants have nowhere become pests of serious economic importance; but in many localities they are very troublesome and annoying in houses, gardens, and orchards. They infest dustbins, and more rarely cupboards in which food is stored. Their large nests are very disfiguring to a well-kept garden. In their search for nectar they will damage the blossom of fruit trees; and they encourage sap-sucking insects, from which they obtain honey-dew, by protecting them from their natural enemies.

Since the establishment of the Division of Economic Entomology at Canberra, numerous requests have been received from the Civic authorities and from local residents for advice on methods of controlling meat ants. In addition, it has been found necessary to eradicate colonies which have threatened the existence of mound-colonies of termites employed in tests of timbers and timber preservatives. Between 1929 and 1933 many nests around Canberra were treated, with varying success; and in the years 1934-1936 a series of experiments involving over 300 nests was carried out to determine the most effective method of control.

2. Description of Nests.

The nests of *I. detectus* vary considerably in size and form. They may consist of a few subterranean galleries with one or two entrance holes, or of a very extensive system of galleries surmounted by a low mound with numerous entrances. The nest is invariably covered with fine gravel; and on this gravel surface vegetable debris, such as pieces of twig, eucalypt fruits, etc., is often placed. The average mound has a diameter of 4 to 6 feet, a height of as many inches, and between

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20 and 30 external openings. Mounds in the forest are noticeably higher than those found in open country. Very large nests are occasionally encountered: for example, one used in our experiments had cross-diameters of 30 to 37 feet, a height of 18 inches, and 1,061 entrance holes. The system of subterranean galleries extends downward to a considerable depth. In excavating a nest to determine its structure, galleries were traced to a depth of 6 feet, beyond which it was found impracticable to follow them.

3. The Occurrence of Multiple Nests.

When the control experiments were started, it was assumed that every nest was inhabited by a complete and separate colony of ants. An investigation of the cause of the frequent repopulation of treated nests, however, soon showed that this was not so; and it was found that more often than not a nest would be merely one of a group of nests between which regular communication was maintained. (The exceptionally large nest mentioned above, for instance, was found to be connected with eleven subsidiary nests spread over an area of about 3 acres.) It seemed reasonable to conclude that each of these groups of associated nests was inhabited by a single large colony; and the results of our experiments supported this supposition.

The occurrence of multiple nests obviously complicates the problem of control; for it means that a nest selected for treatment may be a subsidiary in an associated group of nests, and thus liable to repeated repopulation from the main nest, which might be anything up to 150 yards away. Until this was understood, and control methods modified accordingly, results were obtained in our experimental treatments which were difficult to explain, and moreover gave an erroneous impression of the efficacy of the methods employed. Thus, one nest was found to be repopulated thirteen times, after as many apparently successful treatments. Ultimately it was found that this nest was connected with another some 60 yards away; and when the latter was treated, repopulation ceased.*

Note.—It is not yet known whether a mature colony of *Iridomyrmex detectus* may have more than one queen; but the size and age attained by colonies of this ant, and the analogy of related species, suggest that it may. The results of our experiments with multiple nests indicated, with a fair degree of certainty, that some of the nests comprising an associated group did not contain queens, and, further, that it was not unlikely that the queens (assuming that there are more than one) were confined to one nest. Our employment of the terms "main nest" and "subsidiary nest" might suggest that this was definitely known to be the state of affairs; but no such implication is intended.

4. Materials Tested in Control Experiments.

The following were used in experimental nest treatments:—carbon bisulphide, calcium cyanide, calcium arsenate, white arsenic, Paris green, sodium fluoride, paradichlorbenzene, creosote, and crankcase oil.

* Clark (1), in describing the method he employed for treating meat ants' nests, states that he has "never known a nest so destroyed to be again occupied by ants." It is possible, therefore, that the habit of a colony inhabiting not one but a group of nests is not manifested by these insects in all parts of their very wide range.

Of these nine substances, the first two proved outstanding, and will be discussed in detail below. The remainder, with the exception of Paris green and calcium arsenate, gave unsatisfactory results.

Treatments with Paris green and calcium arsenate were sometimes successful, and one or other of these substances could be used for poisoning nests if neither carbon bisulphide nor calcium cyanide were obtainable. From 1 to 3 oz. per nest should be used, according to size, and the treatment repeated as long as the nest is active. The best way to introduce the powder is with a small hand blower; the type sold by chemists for applying insecticidal powders is quite suitable. The treatment should be carried out in dry weather, and care should be taken to blow some of the poison into every entrance hole on the nest.

5. Fumigation with Carbon Bisulphide.

Carbon bisulphide is not always easy to obtain in small quantities, and has the additional disadvantage of being dangerously inflammable. It was first recommended for destroying colonies of meat ants by Clark (1), who poured the liquid fumigant into the mound, after covering it with wet bags and a layer of earth in order to help retain the fumes inside the nest. In large scale control measures, such as had to be undertaken against the meat ants infesting termite mounds used for testing purposes at Canberra, practical difficulties may be experienced in providing the wet bags recommended by Clark. Tests were accordingly carried out to determine whether these could be dispensed with; and the following modification of Clark's method was found to be quite satisfactory, and has proved, over a number of years, to be thoroughly reliable in its results.

With a crowbar or other suitable tool, a vertical hole, 9 to 12 inches deep, is made in the middle of the mound. Carbon bisulphide is poured into the hole, which is immediately filled with a shovelful of earth and stamped down. (Apparently, owing to the fact that the fumes of carbon bisulphide are heavier than air, the loss of the fumigant through the entrance holes is not sufficient to endanger the success of the treatment.) For nests up to 4 feet in diameter, half-a-pint of the fumigant should be used; one pint for nests 4 to 6 feet in diameter; and proportionately increased quantities for larger nests.*

Treatment should be carried out at times when the ants are congregated in the nest, and not foraging above ground, viz., in the early morning or alternatively in the heat of a sunny summer day. On warm, dull days, most of the inhabitants of a nest are abroad, and our experiments showed that treatments were least satisfactory when carried out under such conditions. This sort of day, however, is ideal for tracing the connexions between a group of nests, *an essential preliminary to undertaking control measures* (see Section 7).

Where mounds are situated on footpaths or in other places where a bar-hole cannot be made, treatment with calcium cyanide (see next section) is recommended.

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* For the treatment of the huge nest mentioned in Section 2 above, a total of 11 pints of carbon bisulphide was poured into fifteen crowbar holes from 14 to 20 inches deep.

6. Treatment with Calcium Cyanide.

The use of this substance for the control of meat ants has been recommended by Summerville (2). Calcium cyanide is obtainable under the trade name of Cyanogas, and is marketed both in powder and fine-granular form. Our experiments indicated that better results were obtained by using the substance in granules (Cyanogas G) than as a powder. The effect of an application of calcium cyanide is spectacular, thousands of dead ants being strewn over the surface of the mound in a very short time.

It is not necessary to confine treatments with calcium cyanide to periods when the ants are congregated in their nests, as it is when carbon bisulphide is used. It is most important, however, to avoid carrying out treatments when the soil is damp or the atmosphere humid. Under these conditions, calcium cyanide is rendered innocuous in a very short time, and a considerable proportion of the colony will escape destruction.

From 1 to 4 oz. of calcium cyanide should be used, according to the size of the nest to be treated; very large nests may require more than 4 oz. The poison can be introduced into the entrance holes either by means of a small hand blower or simply by pouring, the latter method being satisfactory if the granulated form of the substance is used. Care should be taken to treat all entrance holes in the nest, and it is advisable to plug the holes after treatment, as hydrogen cyanide—the gas evolved when calcium cyanide reacts with moisture—is lighter than air, and is liable to escape if the holes are left open.

Once the explanation of the repopulation of treated nests had been discovered, and the simultaneous treatment of all nests in an intercommunicating group was adopted, the use of calcium cyanide was found to give very satisfactory results. About twenty nests in the neighbourhood of the Canberra Hospital were successfully treated by this method, and meat ants practically eradicated from the area. Twelve months after treatment, all but eight nests were uninhabited. Five of these contained very much depleted colonies, while three were found to have been repopulated from nests outside the area.

7. The Treatment of Multiple Nests.

In order to ensure the destruction of the reproductive centre of a colony (and thus something more than temporary freedom from infestation), all the nests inhabited by the colony must be discovered and dealt with. To this end, the following procedure is recommended.

First, a warm and preferably dull day, when the ants are active above ground, should be selected for tracing the connexions between associated nests. If the day is too hot or too cold, the ants will restrict their above-ground activities, and some of the connexions between nests, and thus some of the nests comprising the group, may be overlooked. Although many of the tracks leading from nest to nest will probably be sufficiently well-defined to be followed up whether the ants are using them or not, there will almost certainly be others, traversing pavements or patches of bare hard soil, which are indistinct. As each nest in the group is located, it is a good thing to mark it with a stake or some conspicuous object.

Second, all the nests comprising the group should be treated, one after the other, either with carbon bisulphide or calcium cyanide. If carbon bisulphide is to be employed, no attempt should be made to treat the nests as soon as they have been located, for the conditions which favour the delimitation of a nest-group are not those under which successful results with carbon bisulphide can be expected. The nests should accordingly be left alone until, say, early the following morning, or until it has been ascertained by direct observation that the ants are congregated below ground. If calcium cyanide is to be employed, however, and the air and soil are sufficiently dry at the time, the nests can be treated as soon as they have been located.

It may be mentioned here that some experiments were carried out to determine whether treatment of the main nest only in a group of associated nests would result in the extermination of the colony. Although it was found that the treatment of the main nest usually resulted in the ultimate disappearance of the subsidiary "colonies," we consider it advisable to treat all nests in a group, as it is sometimes impossible to determine which is the main nest.

8. Meat Ants and Termites.

As was mentioned at the beginning of this paper, one of the chief reasons for conducting experiments on methods of meat ant control was the extent to which these insects were attacking mound colonies of termites used in certain timber-testing investigations. The fact that it proved necessary, in this instance, for human beings to intervene and protect the termites from their hereditary enemies might suggest that meat ants play a more important role in controlling termites than they actually do.

Eutermes exitiosus Hill, the termite used for the field-testing of timbers at Canberra, is not normally affected to a serious degree by meat ants. This is indicated by the fact that colonies of meat ants are frequently found nesting on the sunny side of *Eutermes* mounds, and the termites will survive such infestations for many years. We have observed a remarkable instance of a small mound of *E. exitiosus* which had been built in the middle of a very large nest of meat ants, and, judging from the relative sizes of the termite and ant colonies, the former must have been founded in this apparently exceptionally inhospitable situation. Still more remarkable was the fact that, when this termite mound was broken open and treated with crude oil during an investigation of methods of controlling termite colonies, the surviving inhabitants successfully rebuilt their home!

For the assessment of the resistance of timbers to termite attack, and the efficacy of chemical preservatives, samples are installed in a ring round mounds of *E. exitiosus.* As part of an investigation into methods by which attack on such samples could be intensified, the natural food of the termites (i.e., logs, stumps, and standing dead trees) was cleared back to a distance of 50 feet from a number of mounds. A regular outbreak of meat-ant attacks followed, and eight of the mounds from which the natural food had been cleared back eventually died. The attack on some of these mounds was most persistent: one mound was infested on thirteen different occasions by ants from five nests.

The practice of clearing the food from mounds used in field testing has been superseded, and since the time it was discontinued very little trouble has been experienced with meat ants infesting test mounds. It seems clear, therefore, that the removal of their food had a deleterious effect on the vitality of the termite colonies (this conclusion is borne out by the temperature records of their mounds), and in their weakened state they were unable to hold off the attacks of meat ants. There appears to be no reason to believe that a healthy colony of *Eutermes exitiosus* cannot withstand the attacks of meat ants indefinitely.

9. Acknowledgment.

The writer wishes to acknowledge his indebtedness to Mr. G. F. Hill, who was responsible for the meat-ant control work during the early years of the Division, and who was generous with advice and encouragement when the treatment of nests was made the subject of experimental investigation on a wider scale; and to Mr. F. N. Ratcliffe for his generous assistance in the preparation of this paper.

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The Production of Fibres Rich in Hemicelluloses by Controlled Delignification of Australian Hardwoods.

By W. E. Cohen, D.Sc. and H. E. Dadswell, M.Sc.†*

The Division of Forest Products is subsidized by the Australian pulp and paper industry to carry out fundamental investigations relating to the manufacture of pulp and paper from Australian woods. These investigations are mainly concerned with (i) the chemical composition of Australian pulp-woods, (ii) methods of analysis, (iii) a study of the lignin complex, (iv) the structure of the wood fibre and its relationship to the cementing material, and (v) the extractives in wood; they are being dealt with in the Sections of Wood Chemistry and Wood Structure. The co-operation between the officers of these two Sections on the various fundamental problems has led quite unexpectedly to the development of a method for the separation of wood into individual fibres which retain practically all of the total carbohydrate fraction of the wood. This paper is only intended to give a brief history of the experiments leading to this development. The complete results of the numerous investigations referred to in the course of this outline will be published separately.—Ed.

Summary.

Experiments have shown that dilute solutions of sodium hydroxide (0.053–0.16 per cent.) are effective in removing or modifying some non-lignin constituent of the intercellular zone that is concerned in the bonding together of the wood fibres.

This constituent, which is probably associated with the polyuronides of the intercellular layer and cambial walls, can be attacked either before or after the removal of the lignin.

The dilute solutions of alkali have therefore been used in the form of a pre-treatment, using in the first experiments radial sections of *E. regnans* 35μ in thickness.

When the pre-treatment was followed by the delignification procedure employed in the preparation of holocellulose, viz., chlorination followed by solution of the chlorinated lignin in a 3 per cent. solution of ethanolamine in alcohol, the sections quickly separated into fibres which retained approximately 90 per cent. of the furfural-yielding constituents of the wood.

Experiments with both 60 to 80 mesh sawdust and radial sections of *E. regnans* showed that cold 0.08 per cent. sodium hydroxide was a more effective solvent for removing the chlorinated lignin from the wood.

Thus, when an alkaline pre-treatment at boiling temperatures for one hour was followed by chlorination with chlorine water and a final treatment with cold 0.08 per cent. sodium hydroxide, the radial sections readily separated into fibres which were obtained in yields of 66 to 69 per cent. of the original wood, and which retained 85 to 90 per cent. of the furfural-yielding constituents of the wood.

This method of preparation of fibres was therefore applied to shavings from a sample of mature *E. regnans* and from a sample of young *E. regnans* (12 years old) with equally good results.

It was shown, however, that, when the alkali concentration of the pre-treatment liquor was increased to 0.40 per cent. and 1 per cent., there was a decided lowering of the yield and a loss of both cellulose and furfural-yielding constituents.

Most promising results were obtained with the young ***regnans***; the pre-treatment was apparently more effective with this material, and separation into fibres was accomplished very quickly on the addition of the cold alkaline solution to the chlorinated shavings.

The experimental results indicated the possibility of a simplified process for the production of high yields of chemical pulps rich in hemicelluloses; the investigations are being continued.

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1. Introduction.

During recent years, considerable attention has been given to methods for the isolation of all the carbohydrate material occurring in extractive-free wood. The latest method recommended is that developed by Van Beckum and Ritter (1) employing a solution of monoethanolamine in ethyl alcohol as the solvent for the lignin-chloride. By repeated chlorination (using chlorine gas) and extraction with a hot 3 per cent. solution of monoethanolamine in 95 per cent. alcohol, these workers completely removed the lignin from extractive-free wood sawdust (60 to 80 mesh) without loss of any of the carbohydrate material. To this residual carbohydrate material the name "holocellulose" has been given (2), but it would seem more appropriate to describe it as the "Total Carbohydrate Fraction" of the wood. Inasmuch as most of the literature dealing with the isolation of fibres from wood refers to the lignin as the cementing material binding such fibres together, it would appear a simple procedure to treat extracted wood shavings by the method of Van Beckum and Ritter and so obtain "holocellulose" fibres. Unfortunately the removal of all the lignin does not necessarily mean that the fibres will separate. The work of Kerr and Bailey (3) indicated that delignification and maceration were not coincident reactions. They subjected sections of various woods to alternate treatments with chlorine water and 10 per cent. ammonium hydroxide, in either alcoholic or aqueous solution, at room temperature, until they were delignified (as revealed by the Mäule reaction and the fact that they dissolved completely in 72 per cent. sulphuric acid), but these sections did not macerate.

2. Fundamental Investigations.

In experiments carried out with cross and radial sections of various Australian timbers, including *Eucalyptus regnans* and *E. obliqua,* the delignification methods of Kerr and Bailey on the one hand, and of Van Beckum and Ritter on the other, were employed in slightly modified form. In the former case, 3 per cent. ammonium hydroxide in 84 per cent. alcohol was used, while in the latter case, the chlorination was accomplished by chlorine water, and the extraction of the chlorinated lignin, by a cold 3 per cent. solution of monoethanolamine in 95 per cent. alcohol (or in 84 per cent. alcohol); in both cases, the lignin was completely removed as determined by numerous tests. Although the sections were thus completely delignified, there was no evidence of maceration, and under the microscope the cross sections were identical in appearance with the original untreated sections. The next procedure was obviously to determine the nature and solubilities of the bonding material still holding the cells together. The work of Kerr and Bailey indicated that this bonding material was related to the polyuronides and therefore soluble in the standard solvents for these substances. However, experiments revealed that maceration of delignified cross sections was most readily accomplished by means of weak alkaline solutions, 0.04 per cent. to 0.16 per cent. NaOH, by cold monoethanolamine, or, more slowly, by hot water. Even after the second stage of the delignification process, cross sections of spruce, *E. regnans,* and *Tetramerista glabra* (a tropical species of high lignin

content), were macerated by treatment with the weak sodium hydroxide solutions. The bonding material, therefore, whether polyuronide or not, can be readily removed after delignification by such methods.

Kerr and Bailey, in discussing the structure and chemical composition of the so-called middle lamella, have somewhat contradicted themselves in referring to the chemical composition of this intercellular zone. While it must be accepted that there is a high percentage of polyuronides in both the intercellular layer and the cambial wall, referred to by these workers as structural constituents of the so-called middle lamella or intercellular zone, it must be recognized that, in mature wood, the cambial walls at least, and probably the intercellular layer as well, are highly lignified. Since this lignin can be removed chemically without the disruption of the cell arrangement, it is possible to investigate the nature of the other materials acting as bonding agents.

While there is at the present time a lack of sufficient knowledge of the physical and chemical nature of these layers of the intercellular zone, certain experimental facts are clear. Controlled delignification (holocellulose preparation) does not cause maceration even when all the lignin is removed. When such delignification processes are followed by mild alkaline treatments, maceration does occur. In the first step, the carbohydrate fraction remains intact; in the second step, the treatment leading to maceration is so mild that there is little loss of the carbohydrate material. This has been indicated by experiments in which radial sections, 35μ in thickness, from *E. regnans* were employed. These were delignified after four stages of the delignification process, employing chlorine water and treatment with 3 per cent. ethanolamine in 95 per cent. alcohol. They were subsequently completely separated into fibres by stirring vigorously with 0.08 per cent. NaOH at 50°C. for several minutes. The yield of fibres obtained was 67 per cent., and these fibres retained approximately 90 per cent. of the furfural-yielding constituents of the wood. It is logical to assume that some of these furfural-yielding materials are derived from the intercellular layer and cambial walls and remain on the outside of the isolated fibres. The nature of the material removed by the alkali is being investigated.

Having thus accomplished the step of producing fibres with a high percentage of furfural-yielding constituents by delignification followed by treatment with dilute alkali, the possibilities of reversing the treatments were considered. That is to say, possible methods of dissolving or modifying the non-lignin cementing materials before delignification were canvassed. Accordingly, a search was made for a form of pre-treatment which would remove a limited amount of material from the wood with little or no attack on the furfural-yielding substances. For this purpose, extractive-free, 60 to 80 mesh sawdust from *E. regnans* was subjected to various treatments with dilute sodium hydroxide, at different concentrations, at different percentages of alkali to wood, for different periods, and at two different temperatures (25°C. and 100°C.). The results obtained are given in Table 1. It is not intended in this paper to discuss in detail the significance of these results. The work was preliminary in nature and is being supplemented by more detailed experiments, the results of which will be published later. For a given percentage of sodium hydroxide to wood, it appeared

that the amount of material removed was approximately a function of time and of concentration. The losses of furfural-yielding materials increased proportionately with concentration and time, and also apparently with temperature. The experiments indicated that it should be possible to pre-treat wood with hot dilute alkali with the loss of 2 to 3 per cent. of material which forms a lignin-like residue with 72 per cent. sulphuric acid, over and above that removed as hot water solubles, and at the same time to retain most of the furfural-yielding constituents (90 to 97 per cent. of those originally present).

TABLE 1.—EFFECTS OF ALKALINE TREATMENT ON EXTRACTIVE-FREE 60 TO 80 MESH SAWDUST FROM MATURE *E. regnans*.

Reagent.	Conc.	NaOH to Wood.	Temp. Degrees C.	Time, hours.	Loss by Extraction.	Lignin (a). Percentage Original Wood.	Lignin (a). Percentage Loss.	Furfural-yielding Materials Calculated as Xylan (b). Percentage Original Wood.	Furfural-yielding Materials Calculated as Xylan (b). Percentage Loss.
Analysis of original wood						23·0	..	17·9	..
	%	%			%				
Hot water ..	..	..	100	3	2·4	22·0	1·0	17·7	0·2
Sodium Hydroxide	0·053	5·5	25	17	3·7	22·0	1·0	17·8	0·1
" "	0·08	8·0	25	17	4·3	21·4	1·6	17·6	0·3
" "	0·16	11·0	25	17	5·9	21·1	1·9	17·3	0·6
" "	0·053	5·5	100	1	5·9	21·2	1·8	17·3	0·6
" "	0·053	5·5	100	3	7·3	20·9	2·1	16·7	1·2
" "	0·08	8·0	100	1	7·4	20·8	2·2	16·7	1·2
" "	0·08	8·0	100	2	9·0	20·4	2·6	16·4	1·5
" "	0·16	5·5	100	1	8·1	20·7	2·3	16·5	1·4
" "	0·16	16·5	100	1	9·4	20·2	2·8	16·2	1·7
" "	0·50	50·0	100	1	11·2	20·0	3·0	15·7	2·2

NOTES.—All percentages based on the moisture-free weight of the original wood.

(a) Lignin was determined by the method of Ritter, Seborg, and Mitchell (16), using 72 per cent. sulphuric acid.

(b) Furfural was determined by the standard distillation method, using thiobarbituric acid as precipitant (17).

To test the efficiency of a dilute solution of sodium hydroxide as a pre-treatment reagent, radial sections of *E. regnans*, 35μ in thickness, were boiled for one hour with 0.053 per cent. NaOH. The pre-treatment was followed by several stages of the delignification process, using alternate treatments with chlorine water and 3 per cent. ethanolamine in 84 per cent. alcohol. These sections were separated into fibres by stirring, after the second stage, when water washes were employed between treatments, and after the fifth stage, when alcohol washes were employed. The yield of fibres was 69 per cent., and approximately 95 per cent. of the furfural-yielding constituents originally present in the wood was retained. Without the pre-treatment, the radial sections did not separate into fibres even after seven stages of the delignification process, although, as stated previously, lignin, as recognized by various methods, was removed in four stages of this

treatment.* It must be assumed, therefore, that the pre-treatment with mild alkali removed or modified the non-lignin cementing material, thus facilitating fibre separation as soon as sufficient lignin was dissolved.

The importance of obtaining fibres which retained such a high percentage of total carbohydrate constituents of the original wood was fully recognized. Both overseas (4) (5) and in this laboratory (6), evidence has been produced of the correlation between "wood gum" and pulp strength, xylan content and pulp strength, and/or furfural-yielding substances and pulp strength. While in the experiments referred to neither the pre-treatment with very dilute alkali nor the subsequent delignification by the process employed affected the furfural-yielding constituents of the original wood, the means by which the fibres retaining these constituents were obtained could not be considered in any sense commercially practicable.

Consideration was therefore given to other solvents of chlor-lignin, and in this regard the work of Arnold, Simmons, and Curran (7) was highly important. This work indicated that very dilute cold solutions of sodium hydroxide were most effective in dissolving alcohol-soluble chlor-lignin which had been isolated from longleaf pine, and, moreover, that the alkali solution reacted with the isolated chlor-lignin with great rapidity, even at very low concentration (0.04 per cent. to 0.08 per cent.). Their observations suggested the possibility of removing chlorinated lignin from wood substance by means of very dilute cold alkali and without excess of the reagent, so that the furfural-yielding substances need not be attacked or dissolved. Accordingly, parallel delignification experiments were carried out with 100— sawdust of *E. regnans* (previously extracted with boiling water for 30 minutes) and 35μ sections from the same sample of this species (the blocks from which the sections were cut had been boiled in water). The delignification process employed was:—Chlorine gas for five minutes, alcohol wash, stirring with 0.08 per cent. sodium hydroxide (100 ml. per 2 gm. of wood) for 30 minutes at 25°C., cold water wash, 0.1 per cent. acetic acid wash, and final wash with cold water. Since the sections showed no immediate evidence of maceration, the process was twice repeated, after which a reasonable percentage of free fibres was obtained from the sections. At this stage, the wood flour residue was dried and weighed, and the yield found to be 77.6 per cent. of the original material. Analysis of this residue, which contained approximately 0.5 per cent. ash, gave the following results:—

—	Percentage of Residue.	Percentage of Original Wood.	Original Wood.
Furfural-yielding material calculated as xylan	21·7	16·9	% 18·4
Lignin	3·2	2·4	23·1

* Treatments after the fourth stage continued to remove small amounts of material which gave the Mäule reaction, and it is suggested that this indicated a slow decomposition of the non-lignin cementing material resulting in the removal of a phenolic substance, but leaving the associated carbohydrate material between the fibres and holding them together. This carbohydrate material is slightly soluble in cold water, thus explaining the earlier separation when water washes were used.

It will be seen that there was little loss of the furfural-yielding constituents during delignification by this method. Somewhat better results were obtained with 60 to 80 mesh sawdust of *E. regnans* when chlorination was effected by means of chlorine water. Both experiments demonstrated the feasibility of substantially delignifying wood without appreciable loss of carbohydrate material, and revealed a method which might have more practical significance than that in which 3 per cent. ethanolamine in 95 per cent. alcohol is used as a solvent for the chlorinated lignin.

It should be noted that in all the work on sections, and in certain of the work on finely-divided wood, chlorination of the material was carried out by means of chlorine water in preference to chlorine gas. In this way, control of temperature and uniform chlorination of the sections was assured, as well as simplifying the handling of such material. Chlorine water has been used in cellulose determinations from time to time (8), but has generally only been considered in relation to yields. Benjamin and Somerville (9) advocated the use of chlorine water because of the ease of control, and because the quality of the cellulose in relation to the alpha-cellulose content of the wood could be assured. On the basis of the data presented by these workers, chlorine water has been used in this laboratory for several years. On the other hand, Pomilio (10), in setting out claims for his soda-chlorine process which uses chlorine gas, has stated that chlorine water degrades cellulose. The relative merits of chlorination by gaseous chlorine and by chlorine water were consequently investigated; the results of these investigations will be published separately. It is of interest to record here, however, that the copper number (Schwalbe-Hägglund) of the cellulose obtained by the chlorine water method is significantly lower than that of the cellulose obtained when using either undiluted chlorine gas or chlorine gas diluted with cooled air.

When cold 0.08 per cent. sodium hydroxide was used as the solvent for the chlorinated lignin, in conjunction with a pre-treatment for one hour with boiling 0.053 per cent. sodium hydroxide, no difficulty was encountered in obtaining free fibres from 35μ radial sections of *E. regnans* practically instantaneously with the addition of the alkali to the chlorinated sections, or, at most, after a few minutes' vigorous stirring. The concentration of the alkali used in the pre-treatment was varied from 0.04 per cent. to 1 per cent., resulting in yields varying from 69 per cent. to 60 per cent. respectively of the original weight of the sections taken. As the concentration of the alkali for the pre-treatment was increased, the percentage recovery of furfural-yielding constituents in the isolated fibres was decreased from 91 per cent. to 77 per cent. The best results with the sections of this species, from both the point of view of yield and retention of furfural-yielding constituents, were obtained when the concentration of alkali for the pre-treatment was no less than 0.053 per cent. and no more than 0.08 per cent. These preliminary experiments were extended to cover radial sections of *E. obliqua* with equal success.

Other experiments with the sections of young *regnans* have indicated that fibres may be obtained equally easily by reversing the steps of the process. For example, the sections may be chlorinated first, then treated with 0.08 per cent. sodium hydroxide at room temperature for 15 minutes, and finally boiled with a further quantity of 0.08 per cent.

sodium hydroxide for 10 minutes with vigorous stirring. These operations gave a 65 per cent. yield of free fibres, but the percentage recovery of furfural-yielding constituents was somewhat reduced (78 per cent.). A further modification was chlorination followed by treatment with boiling 0.16 per cent. sodium hydroxide with vigorous stirring for 5 minutes. The sections readily separated into fibres giving a 69 per cent. yield, with an 87 per cent. recovery of furfural-yielding constituents. Under these reversed conditions the alkali must react with the chlorlignin and non-lignin cementing material in that order in the first case and simultaneously in the second case.

Following these experiments, a most satisfactory cycle of operations developed for sections of *E. regnans* and *E. obliqua* was found to be: (*a*) one hour pre-treatment with boiling sodium hydroxide of 0.053 per cent. to 0.08 per cent. concentration, (*b*) chlorination for 20 minutes using chlorine water (strength 6 gm. per litre)–100 ml. for 2 gm. original weight of material, (*c*) alkaline wash with 0.08 per cent. sodium hydroxide, with rapid stirring for a few minutes using 250 ml. for 2 gm. of original wood.

3. Pulping Experiments.

In continuance of these more fundamental investigations, the logical sequence was the extension of the experiments to wood in some easily-penetrable form, such as shavings, veneers, or small chips which could be prepared on a commercial scale. The most promising type of raw material appeared to be shavings, and preliminary tests indicated that they would prove satisfactory. The most practical form of shaving, and that employed in most of the experiments, was the *transverse* shaving peeled from a flitch by knives which strike the wood parallel to the long axis of the fibres. These could be cut to any desired length (along the grain) by the aid of scoring knives, and it was found that a length of 1½ inches to 2 inches was convenient for handling during the experimental investigations. Such shavings are fairly uniform in thickness, and their mode of preparation ensures a minimum quantity of cut fibres. Quantities were prepared from a sample of mature *E. regnans* and also from a sample of young *E. regnans* (twelve years old), using the conventional machine planer. The length of the shavings for the experimental work was regulated by means of saw cuts across the flitch. Analytical data of these two wood samples are given in Table 2.

TABLE 2.—ANALYSIS OF WOOD SAMPLES OF *E. regnans* USED IN PULPING EXPERIMENTS.

Material.	Percentage. Extractives.	Percentage Lignin.	Percentage Cross & Bevan Cellulose.	Percentage Total Furfural-yielding material calculated as xylan.	Percentage Furfural-yielding material in C. & B. cellulose calculated as xylan and based on original wood.
Mature *E. regnans*	7·6	21·6	58·0	16·8	11·6
Young *E. regnans*..	2·5	21·1	58·9	19·2	12·4

This type of raw material was used in 100 gm. (moisture-free) quantities for laboratory pulping experiments.

For the pre-treatment, the shavings were heated in a large beaker with water and the appropriate amount of alkali to give the desired concentration. It was found inconvenient to work at a liquor ratio of much less than 30 to 1. After bringing to the boil, the heating was continued for one hour, when the liquor was removed and the shavings washed with hot water to remove alkali and soluble matter. For the determination of alkali requirement, it was necessary to take into consideration the alkali consumed by the water solubles of the wood. This amount may vary with the concentration and with the total amount of alkali present. By using the 60 to 80 mesh sawdust samples from both the mature and young samples of *E. regnans* investigated, it was shown that when heated for one hour at 100°C. with alkali at 0.08 per cent. concentration, the following amounts of sodium hydroxide would be consumed by the water solubles:—

Mature *E. regnans* .. 2.2 per cent. sodium hydroxide to wood.
Young *E. regnans* .. 0.6 per cent. sodium hydroxide to wood.

Following the results outlined in Table 1, it was determined that during the pre-treatment of the wood and modification of the chemical constituents of the intercellular zone, the alkali consumption would be:—

Mature *E. regnans* .. 5.2 per cent. sodium hydroxide to wood.
Young *E. regnans* .. 4.6 per cent. sodium hydroxide to wood.

These amounts were obtained with respect to a pre-treatment using excess alkali at 0.08 per cent. concentration on 60 to 80 mesh wood. They are therefore only approximations to the amounts actually consumed during the pre-treatment on shavings with limited amounts of alkali, but the results were used in calculating the alkali to be added to give the required amount for chemical reaction with the intercellular zone, over and above that necessary for neutralization of the water-solubles. Details of alkali concentration, ratio of alkali to wood, liquor ratio, time, and temperature of pre-treatment have been set out in Table 3.

The chlorination of the pre-treated shavings was accomplished in 4-lb. Mason jars, using 1 litre of chlorine water to 50 gm. (moisture-free) of shavings. Continual mixing was effected by tumbling the jars in a bleach tank. For complete chlorination, it was found necessary after 20 minutes to replace the chlorine water with a fresh supply. The strength of the chlorine water used was 6 gm. per litre, and, assuming that no losses occurred during the handling of the solution, there was in each case 24 per cent. of chlorine available for chlorination. Although losses were inevitable, it was always found that there was an excess of chlorine after the second treatment, so that it is safe to assume a chlorine consumption slightly above 20 per cent. When 60 to 80 mesh sawdust of both mature and young *E. regnans* was treated with excess chlorine (45 per cent.) for 40 minutes at 20°C., the consumption was approximately 26 per cent. Thus, although free chlorine was detected after the treatment of the shavings, the consumption was lower than for 60 to 80 mesh sawdust. This may be explained by the greater penetration and reactivity of the

TABLE 3.—PULPING DETAILS, YIELDS AND ANALYSES OF PULPS.

Wood.	Pulp Ref. No.	Pretreatment Details.					Chlorination.	Alkali Wash (a).		Pulp Yield.	Free Fibres Percentage of Pulp (b).	Total Xylan (c).		Lignin Percentage of Pulp.	C. and B. Cellulose.		Xylan (c) not in Cellulose.	
		NaOH to Wood.	NaOH Conc.	Liquor Ratio.	Time Hours.	Temp. °C.	Maximum Chlorine Available.	NaOH to Wood.	Stock Conc.			Percentage of Pulp.	Percentage of Wood.		Percentage of Pulp.	Percentage of Wood.	Percentage of Pulp.	Percentage of Wood.
(1)	(2)	% (3)	% (4)	(5)	(6)	(7)	% (8)	% (9)	(10	% (11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)
Mature *E. Regnans.*	6	5 + 2·2	0·053	93	1	100	>24	7·0	3·5	67·3	..	22·1	14·8	2·6	86·6	58·3	..	..
	15	5 + 2·2	0·08	62	1	100	<24	7·0	4·5	67·4	77·5	22·0	14·8	3·8	87·5	58·9	3·16	2·13
	16	10 + 2·2	0·08	124	1	100	<20 (d)	7·0	4·5	68·8	65·0	21·6	14·9	6·0	85·5	58·8	2·96	2·04
	14	5 + 2·2	0·08	62	2	100	<24	7·0	4·5	66·6	..	22·5	15·0	3·5	88·2	58·7	3·49	2·32
	11	6 + 2·2	0·16	37	1	100	<24	7·0	4·5	67·4	69·0	21·5	14·5	4·6	87·3	58·8	3·07	2·07
	13	15 + 2·2	0·40	31	1	100	<24	7·1	4·5	64·4	76·5	22·2	14·3	3·0	88·7	57·0	3·63	2·28
	21	30 + 2·2	1·00	31	1	100	<24	7·0	4·5	62·4	83·5	22·6	14·1	2·6	91·0	56·8	2·93	1·83
	7	10 + 2·2	0·16	31	18	20–25	<24	7·0	3·5	70·6	..	21·2	14·9	6·1	82·3	58·1	3·67	2·59
	20	30 + 2·2	1·00	28	16	20–25	<24	7·0	4·5	67·9	..	21·8	14·8	4·2	85·9	58·3	3·49	2·37
		Analysis of 60–80 mesh wood from same sample.											**16·8**	..	..	**58·0**	..	**5·2**
Young *E. regnans.*	22	5 + 0·6	0·16	31	1	100	<24	7·3	4·5	67·4	..	23·3	15·7	2·5	88·5	59·6	4·10	2·76
	26	5 + 0·6	0·08	62	1	100	<24	7·2	4·0	69·0	83·0	23·6	16·3	3·7	85·8	59·2	4·99	3·44
	28	5 + 0·6	0·053	93	1	100	>30	7·2	4·0	68·8	91·0	23·4	16·1	2·8	84·9	58·4	5·17	3·56
		Analysis of 60–80 mesh wood from same sample.											**19·2**	..	..	**58·9**	..	**6·8**

NOTES.—(a) Carried out at room temperatures.
(b) The actual free fibres were floated from the fibre bundles and shives.
(c) Furfural-yielding materials calculated as xylan (see reference, Table 1).
(d) Under-chlorination recorded at time of test.

All percentages expressed on the moisture free weight of the pulp or wood.

sawdust in comparison with the shavings. After chlorination, the shavings were well washed with water to free them both from acids and from as much water-soluble chlor-lignin as possible.

In all experiments, the final alkaline treatment and disintegration of the shavings was carried out in the British Standard Disintegrator. The shavings were placed in the disintegrator with sufficient water to give a stock concentration of 4.5 per cent. with mature *regnans,* and 4.0 per cent. with young *regnans.* After starting the propeller, sodium hydroxide, in the convenient form of a 10 per cent. solution, was quickly added in sufficient quantity to give 5 per cent. of the original moisture-free weight of wood. The alkali was rapidly neutralized, and the fibres separated immediately. After five minutes, the stock no longer gave an alkaline reaction, so additional sodium hydroxide was added at intervals to keep it alkaline, and to bring the total percentage of alkali to 7 per cent. of the original moisture-free weight of wood. This generally occurred after 15 to 18 minutes of stirring, at which time the reaction was practically complete, and the stock remained alkaline. The disintegrator was kept running for a total time of 30 minutes. The pulp so formed was filtered, washed with water, and soured with very dilute hydrochloric acid (less than 0.01 per cent. concentration). The latter treatment facilitated washing, reduced the ash content to practically nothing, and improved the colour of the pulp. Apparently, excess alkali remained on the pulp, either adsorbed or in chemical combination, and rendered the pulp difficult to wash. The washed pulp was hand pressed to approximately 20 to 24 per cent. total solids, mixed, weighed, and sampled for total solids determination. The yields obtained in the various treatments, calculated as percentage of original moisture-free wood, are shown in Table 3. Samples of each pulp were air-dried for chemical analyses, the results of which are also included in Table 3. There were few bad shives in any of the pulps, although there was a certain percentage of fibre bundles or fine splinters (from the centres of the thicker shavings). These would, presumably, be readily broken up by mechanical processing. For certain of the pulps, an actual determination of the percentage of free fibres was carried out by a flotation method, and the results have been recorded in Table 3, column 12. The highest values were recorded for pulps 26 and 28 from young *regnans,* and pulp 21 from mature *regnans.* It must be realized that, on a larger scale, any large shives and splinters which would not respond to mechanical processing could be screened and returned for further chlorination.

4. Discussion.

The pulping experiments which have been described are preliminary only, and have to be confirmed on a larger scale. However, the simplicity of the operations, and the high yields of pulp in which 84 per cent. to 89 per cent. of the furfural-yielding constituents of the wood has been retained, make the results of considerable interest. Sufficient material for pulp evaluation tests is being prepared. As mentioned earlier, evidence has been produced of the correlation between furfural-yielding constituents and pulp strength. Davis (11) has found that the bursting strength of the pulps prepared by cooking with dilute

alkaline liquors is from 50 per cent. to 100 per cent. higher than that of commercial pulps. His yields of bleached aspen pulp varied from 56 per cent. to 59 per cent., the most desirable method giving the lower figure. When his figures for the pentosan content of the original wood and that of the bleached pulp are considered, it is seen that he has retained only 54 per cent. to 57 per cent. of the furfural-yielding constituents, yet his pulps are significantly stronger than commercial soda pulps. There is, therefore, some justification for the assumption that the pulps produced by the methods described in this paper will have a higher strength than is usual for commercial pulps.

When considering the results given in the tables, it should be borne in mind that the furfural-yielding constituents have been calculated and recorded as xylan. This procedure is convenient for comparison purposes, although it is fully recognized that other polysaccharides, which yield furfural in smaller amounts, may be present. The polyuronides referred to by Kerr and Bailey as occurring in the intercellular layer and cambial walls will, if remaining with the pulps, have been recorded as xylan.

The results in Table 3 have been arranged in two main groups, the first relating to the pulps from the mature *regnans* and the second to those from young *regnans*. Consideration of the results in both groups shows that the concentration of the alkali in the pre-treatment liquor is an important factor. When this concentration was kept between 0.053 per cent. and 0.16 per cent., the yield remained much the same, although there is some evidence of slightly greater attack on the furfural-yielding constituents in the case of pulp 11. However, as the concentration of the alkali was increased to 0.40 per cent. in the case of pulp 13, and 1.0 per cent. in the case of pulp 21, the yields decreased appreciably, and there was a perceptible loss of the furfural-yielding constituents (based on original wood—see column 14). In the case of pulps 13 and 21, there is also evidence of degradation of the cellulose as shown by the lower yields—see column 17. That these effects are not due to the increased quantity of alkali present in the pre-treatment liquors (column 3) is indicated by results for pulp 16, which was prepared under exactly the same conditions as pulp 15, but with twice the amount of alkali. That is, for pulp 16, the percentage of sodium hydroxide to wood was 10 instead of 5, although the concentration was maintained at 0.08 per cent. Unfortunately, there was evidence of under-chlorination in the case of pulp 16, and the lignin content of this pulp was therefore higher than for others listed in Table 3. However, in other respects, pulp 16 showed no difference from pulp 15, the recovery of furfural-yielding constituents and of cellulose being practically identical.

The shavings from the young *regnans* separated into fibres very readily under the conditions of the treatment outlined. This may have been due to their higher moisture content (60 per cent. compared with 20 per cent. for the mature *regnans*), thus allowing a better penetration during the pre-treatment period. In the final alkaline wash to dissolve the chlorinated lignin, the reaction was practically instantaneous, and the fibres separated immediately, leaving only a small proportion of fine splintery shives. With such raw material, the pre-treatment with alkali of 0.16 per cent. concentration was probably a little severe, as

the yield was lower and there was some reduction in the amount of furfural-yielding constituents recovered (compare results for pulps 22, 26, and 28). The recovery of these constituents was not as high as in the case of the mature *regnans* even under the most favourable conditions. This may have been due to the use of too high a percentage of avaliable alkali in the case of the young *regnans* or, alternatively, to the diminished solubility of the carbohydrate material of the mature *regnans* as a result of drying or of the ageing of the wood.

Pulps 7 and 20 show what may be expected from a cold alkaline pre-treatment at somewhat higher concentrations. The yields and pulp analyses do not differ very markedly from those obtained with hot pre-treatments at lower concentrations. Experiments on a small scale using 35μ radial sections showed that cold pre-treatment at 0.08 per cent. concentration was equally effective when 10 per cent. or more of available alkali was used. For a more economic liquor ratio, however, the work was carried out at higher concentrations.

During the course of all these experiments, it was observed that under chlorination resulted in a high lignin content of pulp and a higher percentage of shives and fine splintery fibre bundles. This was, in general, irrespective of the pre-treatment, and it was therefore apparent that adequate chlorination is essential for the most satisfactory preparation of fibres by this method. Free chlorine, to the extent of approximately 24 per cent. on the basis of the moisture-free weight of original material used, was necessary for the best results. It is of definite interest to record how rapidly and effectively the cold alkaline solution in the final treatment removes the chlorinated lignin. It seemed, however, that, even under the best conditions, the pulp retained between 2.5 per cent. and 4 per cent. of lignin (see column 15, Table 3).

The experiments with cross and radial sections of *E. regnans* clearly prove that treatment with dilute sodium hydroxide removes or modifies some non-lignin material concerned in the bonding together of the wood fibres. This material must be associated with the polyuronides of the intercellular layer and the cambial walls, and can be attacked by the alkali either before or after delignification. It is probably a complex* which yields a lignin-like residue on treatment with 72 per cent. sulphuric acid, is readily hydrolysable with dilute alkali, and may consist of a polysaccharide in association with a phenolic substance, the latter giving the chlorine sodium sulphite colour reaction (12). This colour reaction has been obtained with the filtrate after holocellulose, prepared from *E. regnans* by seven stages of the delignification treatment, has been warmed at 50°C. with 0.08 per cent. sodium hydroxide, or boiled with water. It is almost certain that, in order to obtain a holocellulose free from the abovementioned phenolic substance, small losses of carbohydrates associated with it are inevitable, especially when water washes are used. This complex is apparently not identical with the lignin, although the phenolic substance formed by hydrolysis is probably related to the water-soluble material isolated simultaneously with methanol-lignin (13). Cohen and Harris (14) readily removed this water-soluble fraction (approximately 6 per cent.)

* For example, a saponin or similar glucosidic substance, the presence of which would readily explain the copious frothing which occurs when hardwoods or their total carbohydrate fractions are boiled with water, dilute alkali, or dilute acids.

from maple by hydrolysis with 3 per cent. sulphuric acid, and slowly removed a portion of it by extraction with hot water. The main bulk of the lignin was shown to be resistant to such treatments. The earlier work of the authors (15), which showed that curves relating lignin content with time of extraction quickly flattened when various woods were extracted with hot dilute sodium hydroxide, may be regarded in a different light. It appears, now, that the alkali, in addition to removing extraneous substances, modifies and removes the unidentified material which would normally yield a lignin-like residue with 72 per cent. sulphuric acid. In tissue differentiation, it is probable that the complex referred to functions as a precursor of both carbohydrate and lignin, the phenolic portion during lignification becoming a building unit of the more stable lignin polymer. It is obvious that in order to clarify the position it will be necessary to investigate the chemistry of the cambium.

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The Relation between Colour and Chemical Composition in Soils.

By A. B. Beck, M.Sc.*

Summary.

An attempt has been made to study the relationship between the colours of 32 soils, and the calcium carbonate, humus, and free iron oxide contents.

The method of Drosdoff and Truog for the estimation of free iron oxide does not appear to give an absolutely sharp distinction between free iron oxide and iron combined as silicate.

Calcium carbonate has the effect of darkening the colour due to humus in certain soils.

The yellow colour of some podsolic subsoils cannot be removed by a treatment which removes free ferric oxide, and appears to be intrinsic to the mineral colloid of the soil.

In grey, black, and white soils, the free iron oxide is probably very low, while in normal brown and red soils, free ferric oxide and humus are the pre dominating colouring materials.

In certain red soils of basaltic origin, the colour seems to be due in part to the presence of a brown complex iron silicate.

1. Introduction.

It is generally considered that the colours of soils are due to two main factors, the so-called "humus," which is responsible for a black or dark-brown colour, and free ferric oxide, which is assumed to give a red or yellow colour according to the degree of hydration. Certain other minor constituents such as magnetite, pyrolusite, and ferrous compounds probably contribute to the colour of certain soils, and it is also recognized that some soils with a high lime status have rather a darker colour than would be expected from their humus content. It has apparently been tacitly assumed that iron silicates are of very minor importance in determining the colour of soils. Any attempts in the past to correlate soil colour and chemical composition have been hindered by the lack of a chemical method of estimating free ferric oxide, most methods being too drastic and resulting in the decomposition of silicates.

In 1935, Drosdoff and Truog (1935) brought forward an entirely new method for the estimation of iron oxide based on its reaction with H_2S to give an easily soluble iron sulphide, a reaction which has been applied for many years in the purification of coal gas. The writers claimed that iron silicates remained unattacked. The present project was made possible by the application of this new method, and was an attempt to correlate the chemical composition with the colour of 23 soils which had been chosen by the Division of Soils as representing a range of typical colours likely to be encountered during soil surveys. A number of additional soils were also investigated to obtain further

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information on the analytical method for free iron oxide. The soils used had all been taken as type samples in soil surveys, and a considerable amount of chemical and physical data was already available. The present investigation was confined to the estimation of free ferric oxide, humus, and, in some cases, manganese oxide.

2. Experimental.

In preliminary experiments on Waite Institute soils, it was found that, using Drosdoff and Truog's original method in which the soil was allowed to react with the H_2S for 30 minutes, the residues were still definitely red to red-brown in colour. A second treatment brought out a considerable amount of ferric oxide, and the residues were of a very pale colour. It was considered that the residual red colour after the first extraction was due to unattacked ferric oxide, and, accordingly, it was decided to increase the time of reaction with H_2S to six hours. This period is more or less arbitrary, but, from the experiments with this type of soil, an extraction of six hours was necessary to give reasonably pale residues and hence a complete extraction of the free ferric oxide. It was realized that decomposition of complex silicates containing iron might also be taking place, but, as it was desired to obtain the colour of a soil free from iron oxide, it was considered better to have all the ferric oxide removed even if small proportions of the silicates were decomposed. In some cases where the residue was still strongly coloured after six hours, a second extraction was given. The significance of the residual colours is discussed later.

The following modified method was adopted for the determination of free ferric oxide:—5 gm. of the air-dry soil was treated in the cold with sufficient N/20 HCl to decompose carbonates and humates. With soils rich in carbonates, N/10 acid was used. The acid was decanted off after centrifuging, and the residue washed several times with water. The residue was transferred to a beaker and sufficient 100 vol. hydrogen peroxide added to make the suspension equivalent to 20 vols. per cent. The suspension was allowed to stand on a steam bath for one hour (or longer if necessary) to decompose and bleach the organic matter. The suspension was centrifuged and washed once, potassium nitrate being added as a coagulant if necessary. The residue was then treated on a steam bath with 150 ml. of 2 per cent. sodium carbonate to remove colloidal silica. The suspension was then centrifuged and washed several times with the sodium carbonate solution; the soil was left as the sodium-complex so as to facilitate dispersion. After centrifuging, the residue was hand dispersed with a rubber pestle and mortar, 2 ml. of N ammonia added, and the volume made up to about 200 ml. The suspension was dispersed by shaking overnight in end-over-end shakers and transferred to a 500 ml. Erlenmeyer flask, saturated with H_2S (20 mins.), and agitated for six hours. The iron sulphide thus produced was dissolved with 0.1 N hydrochloric acid as described by Drosdoff and Truog, and the iron estimated by cupferron or permanganate. When a second extraction was to be done, the residue was hand dispersed with 4 ml. N ammonia and 200 ml. water, saturated with H_2S, and allowed to shake overnight. The iron sulphide was dissolved as before. The sulphur in the residue was removed by means of an alcoholic solution of carbon disulphide.

The humic matter of the soils was determined by the method of Eden (1924) who extracts an acid-treated soil with hot 10 per cent. caustic soda. A solution of Merck's "Acidum Huminicum", as standardized by the method of Hoffmann (1933), was used for comparison. It will be noted in the following tables that the percentage of humic material, hereafter simply termed "humus," represents only a small proportion of the total organic matter as indicated from the figures for organic carbon.

The results, together with chemical and physical data compiled from the Division's records, are set out in Tables 1-4.

The standards of colour and the corresponding Ridgway standards have been briefly discussed by Taylor (1935). The colours of the samples, and also of the residues, after the various treatments were assessed by Mr. J. K. Taylor.

The term "off" after a colour indicates that the colour is not quite the same as the standard colour.

In the other columns, the figures in the "Free Fe_2O_3" column represent the ferric oxide from each extraction as numbered. The colour given in the "Colour after removal of free Fe_2O_3" column represents the colour after removal of $CaCO_3$, humus, and Fe_2O_3. All analytical figures are for air-dry material.

3. Discussion of Results.

The first point of interest is that appreciable amounts of silica are extracted from the soil along with the iron oxide. Two parallel estimates were made on soil U153, in one the complete extraction was done, and in the other the treatment with H_2S was omitted, the dispersed soil being simply treated with N/10 HCl. No iron was extracted in this second treatment, but the amounts of silica and alumina extracted in both cases were the same, hence in this case at least, the silica dissolved arose from the action of the dilute hydrochloric acid on the aluminium silicates and not from decomposed iron silicates.

Considering the data of the grey and black soils (Table 1), perhaps the most outstanding feature is the effect of the small percentage of calcium carbonate on the colour of soils 876 and 2328 as set out in Table 4. These soils were originally dark grey and grey-black respectively, and after the removal of calcium carbonate alone the colours become light grey and grey respectively. The intensifying effect of the carbonate is shown by a comparison of soils 207 and 876. The first, an acid podsol, has five times as much humus as soil 876, and yet the first is only a "grey" as compared with a "dark grey" of the calcium carbonate soil. Robinson (1936) mentions the effect but offers no suggestion as to the cause. This may be due either to an increased dispersion of the humus, or to an increased ionization of the humic acid as the calcium salt, or to both reasons. The fact that the residues, after removal of calcium carbonate and humus, have no visible red or brown tint, and the observations that small amounts of ferric oxide have a strong tinctorial effect, suggest that with the soils of Table 1 the iron oxide extracted by the treatment is primarily derived from silicates.

The yellow soils (Table 2) gave some interesting results. The treatment of soils 4242 and 2014, both podsolic subsoils, brought out definite amounts of iron oxide without appreciably altering the colour. Soil 3941 showed a similar effect, although the presence of fine limonite renders this observation of less value. It is considered that the yellow colour in these soils is intrinsic to the soil colloid, and is not due to free hydrated ferric oxide. Further work on the separated mineral colloid of yellow podsolic subsoils would give further information along these lines. It is considered that the iron oxide extracted from 4242 and 2014 is derived from the decomposition of silicates.

Passing on to red and brown soils in Table 3, we have soils in which the colour is probably largely due to free ferric oxide. The ferric oxide causing the colour is apparently present as a film over the soil particles, and the greater the percentage of clay and hence the greater the surface area, the greater the amount of oxide necessary to give it a definite colour. Thus 2299, a coarse sand, has only 0.71 per cent. ferric oxide, 1231, a loamy sand with 11 per cent. clay, has 1.42 per cent., and 1016, a heavy clay soil with 62 per cent. clay, has between 14 and 18 per cent. free iron oxide, and yet the colour of these three soils is substantially the same. It is probable, too, that once the coating of ferric oxide reaches a certain thickness, the colour will be unaffected by increased ferric oxide.

The colours of the residues after removal of free iron oxide call for comment. In most cases the colours are very pale and, where red or brown, are probably due to veins of ferric oxide running through sand grains and hence not accessible to the H_2S. This is true of all the soils derived from sedimentary deposits, but with some of the soils of basaltic origin (1016 and 1982) there is a very definite residual brown colour which is apparently due to some complex iron silicate. In soils 1218 and 3902 (also of basaltic origin), the fact that the humus free residues have little red in their colour makes it probable that most of the iron oxide extracted is from silicates.

4. Acknowledgments.

The writer wishes to acknowledge his indebtedness to Professor J. A. Prescott of the Waite Institute, who suggested the above investigation, and who gave much helpful advice and criticism; also to Mr. J. K. Taylor for the assessment of the colours of the soils and the residues after treatment.

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TABLE 1.—WHITE, GREY, AND BLACK SOILS.

Soil No.	Colour.			Humus.	Free Fe_2O_3.	Clay.	pH.	Other Data.
	Original.	After Removal of—						
		$CaCO_3$ and Humus.	Free Fe_2O_3.					
				%	%	%		
2519	Very light grey to white	* ..	Very light grey ..	0·10	0·11	49·9†	..	McGillivray, Kangaroo Island. 30–42″. $CaCO_3$ 62·2 per cent.
207	Grey	Very light yellow grey	White (off) ..	1·06	0·56	14·2	5·2	Myponga, S.A. 0–9″. Contains unhumified organic matter
1917	Light grey ..	White (off) ..	White to very light grey	0·18	0·24	4·1	5·7	Kuitpo, S.A. 0–12″. N. 0·03 per cent. Contains unhumified organic matter
876	Dark grey ..	White, slightly yellow*	White	0·22	0·49	56·0	8·6	Wimmera, Vic. 0–12″. Org. C. 0·50 per cent; $CaCO_3$ 3·7 per cent.
2328	Grey black ..	White (off)* ..	White (off) ..	0·35	0·23	30·4	8·9	Madras, India. Surface. Org. C. 0·32 per cent.; $CaCO_3$ 5·2 per cent.; Mn_3O_4 0·053 per cent.
1473	Black	Light grey ..	White (off) ..	3·0	0·42	59·0	8·4	Glenlossie Swamp, River Murray. 0–12″. Mn_3O_4 0·11 per cent.; $CaCO_3$ 0·06 per cent.

* See Table 4 for the effect of removal of $CaCO_3$ alone.

† NaBrO method.

TABLE 2.—YELLOW AND LIGHT BROWN SOILS.

Soil No.	Colour. Original.	Colour. After Removal of— CaCO$_3$ and Humus.	Colour. After Removal of— Free Fe$_2$O$_3$.	Humus.	Free Fe$_2$O$_3$.	Clay.	pH.	Other Data.
				%	%	%		
4242	Light yellow ..	Very light yellow	(1) Light yellow (2) Very light yellow	0·50*	(1) 0·47 (2) 0·48	39·2	4·9	Denmark, W.A. 24–36″
2014	Yellow ..	Yellow brown to yellow	(1) Yellow to light yellow (2) Yellow to light yellow	0·02	(1) 0·78 (2) 0·78	36·6	5·7	Kuitpo, S.A. 16–27″
3941	Light brown, some yellow	Light yellow brown	Light yellow ..	0·19	3·17†	27·3	6·3	Denmark, W.A. 19–27″
2598	Grey yellow ..	Light yellow to yellow	(1) Very light grey yellow (2) Light grey, slightly yellow	0·13	(1) 0·86 (2) 0·67	52·9	7·5	Willalooka, S.A. 6–20″. Contains unhumified organic matter
3711	Yellow-brown ..	Light yellow brown	(1) Very light yellow (2) .. .. (3) Very light grey to white	0·09	(1) 1·40 (2) 0·98 (3) 0·28	42·6	8·4	Marabel, S.A. 14–27″. Org. C. 0·22 per cent.
1827	Light brown ..	Light brown ..	Buff	0·06	0·54	21·7	8·6	Renmark, S.A. 12–27″. CaCO$_3$ 9·8 per cent.
4550	Light grey brown (slightly off)	Very light yellow brown	White, slightly yellow	0·01	0·50	24·0	8·3	Curlwaa, N.S.W. 18–30″. CaCO$_3$ 0·85 per cent.

* Soluble in acid 0·13 per cent. Soluble in alkali 0·37 per cent.

† This soil contained much nodular limonite. The coarser fraction was sieved out before using, but the sample used still contained much fine limonite.

TABLE 3.—RED AND BROWN SOILS.

Soil No.	Colour.			Humus.	Free Fe_2O_3.	Clay.	pH.	Other Data.
	Original.	After Removal of—						
		$CaCO_3$ and Humus.	Free Fe_2O_3.					
				%	%	%		
1231	Red	Light red brown to red brown	Light grey brown	0·28	1·42	11·1	5·8	Roto, N.S.W. Mallee: Surface
1016	Red, stronger than 1231	Red brown to red	(1) Brown, slightly red (2) Brown	0·65	(1) 14·2 (2) 4·5	63·4	5·4	Basaltic loam. Woolongbar, N.S.W. 18–27″. Mn_3O_4 0·08 per cent.; org. C. 1·44 per cent.
	Red	.. ..	(1) .. .. (2) Brown, slightly red	..	(1) 13·4 (2) 5·9	100·0	..	Clay separated from 1016. Total Fe_2O_3 29·6 per cent.
2299	Red brown to red	Red brown to red	Light brown ..	0·06	0·71	7·7	..	Gibson's Desert. Surface. Coarse sand, 62·0 per cent.
3816	Dark red to red	Light red ..	Very light brown	0·35	3·02	41·8	7·4	Yarcowie, S.A. 5–14″. Org. C. 0·58 per cent.
1982	Chocolate ..	Dark red brown*	(1) Brown .. (2) Brown ..	1·04	(1) 7·3 (2) 2·8	31·3	8·4	Atherton Tableland, Q. Surface. N. 0·015 per cent.; Mn_3O_4 1·78 per cent.
2776	Light red brown	Light brown, slightly red	Very light yellow brown to buff	0·01	0·52	12·9	..	Berri, S.A. 33–57″. $CaCO_3$ 1·19 per cent.
2818	Dark red brown	Light red brown	Very light grey brown	0·26	1·03	10·9	8·1	Berri, S.A. 0–15″
3496	Brown ..	Brown to light brown	Buff	1·50	1·62	17·4	6·4	Waite Institute. Surface: N. 0·115 per cent.
3467	Grey brown ..	Light brown to light yellow brown	White (very pale buff)	0·07	0·62	49·1	..	Mirrool, N.S.W. 27–42″

* Also after removal of Mn_3O_4.

TABLE 3.—RED AND BROWN SOILS.—*continued.*

Soil No.	Colour. Original.	After Removal of— CaCO$_3$ and Humus.	After Removal of— Free Fe$_2$O$_3$.	Humus.	Free Fe$_2$O$_3$.	Clay.	pH.	Other Data.
				%	%	%		
3635	Dark brown ..	Brown to light brown	Light grey to light grey brown	0·73	1·23	27·0	..	Mirrool, N.S.W. 0–10″. CaCO$_3$ 2·13 per cent.
3902	Dark grey brown	Light grey to grey*	Very light grey ..	3·1	2·10	48·1	..	Bundaberg, Q. 0–6″. Mn$_3$O$_4$ 0·03 per cent.; N. 0·19 per cent.; CaCO$_3$ 0·65 per cent.
1218	Very dark brown	Grey brown, slightly light brown*	(1) Light grey brown (2) Grey to light grey brown	3·6	(1) 4·9 (2) 1·4	41·5	7·3	Ilparran, N.S.W. 0–9″. Alluvial, derived from basalt. Mn$_3$O$_4$ 0·37 per cent.; org. C. 3·06 per cent.
U151	Dull brown ..	Brown to light brown	(1) .. .. (2) White to very light grey	1·53	(1) 1·62 (2) 0·52	18·0	6·0	Waite Institute profile, 0–4″. Org. C. 1·32 per cent.
U152	Dull brown ..	Brown to light brown	(1) .. .. (2) Very light grey	1·02	(1) 1·88 (2) 0·62	21·8	5·8	4–9″. Org. C. 1·07 per cent.
U153	Brown ..	Light red brown to brown	(1) .. .. (2) Very light grey	0·59	(1) 3·71 (2) 0·97	47·4	6·3	9–18″. Org. C. 0·76 per cent.
U154	Brown, slightly red brown	Light red brown to brown	(1) .. .. (2) Very light grey	0·41	(1) 3·89 (2) 1·28	59·9	6·7	18–27″. Org. C. 0·67 per cent.
U155	Brown ..	Light red brown to brown	(1) .. .. (2) Very light grey	0·45	(1) 3·70 (2) 1·02	59·2	7·2	27–36″. Org. C. 0·66 per cent.; CaCO$_3$ 0·13 per cent.
U156	Dull brown ..	Brown to light brown	(1) .. .. (2) Very light grey	0·34	(1) 2·30 (2) 1·12	40·7	8·4	36–45″. Org. C. 0·41 per cent.; CaCO$_3$ 4·8 per cent.
U157	Dull brown ..	Brown to light brown	(1) .. .. (2) Very light grey	0·26	(1) 2·22 (2) 1·14	37·2	8·4	45–54″. Org. C. 0·30 per cent.; CaCO$_3$ 3·96 per cent.

* Also after removal of Mn$_3$O$_4$.

TABLE 4.—SOILS SHOWING COLOUR CHANGES AFTER THE REMOVAL OF CALCIUM CARBONATE ALONE.

Soil.	Colour.			$CaCO_3$
	Original.	After removal of—		
		$CaCO_3$.	$CaCO_3$ and Humus.	
				Per cent.
876	Dark grey ..	Light grey ..	White, slightly yellow	3·7
2328	Grey black ..	Grey	White (off) ..	5·2
2519	Very light grey to white	Grey to light grey	.. .. ..	62·2
2776	Light red brown	Brown to light brown, slightly golden	Light brown, slightly red	1·2

NOTE.—In all other calcareous soils and No. 1473 no colour change was noted on the removal of the $CaCO_3$.

The Role of Wood Anatomy in Forest Botany.*

By H. E. Dadswell, M.Sc.†

Summary.

Since the formation in 1930 of the International Association of Wood Anatomists, the science of wood anatomy has developed rapidly, and, as a result of the intensive research of recent years, it is in a position where practically every woody species of any importance has been investigated and can be identified on the basis of wood structure alone. As a result of this work, the wood anatomist can now offer definite assistance to the botanist as well as to commercial interests. This assistance may lie (i) in the classification of certain genera where botanical confusion exists, (ii) in the study of the internal arrangement of families, and (iii) in the determination of the probable affinities of doubtful families.

Definite examples of such services to the botanist have been quoted, and especial reference has been made to cases of local importance. It has been suggested that the time is opportune for greater co-operation between the botanist and the anatomist, and that with every field collection of material for systematic study a representative sample of the wood from the same tree should be included for future reference.

During the past decade, the study of wood anatomy has been tremendously stimulated. This is evident by the remarkable increase in the number of publications dealing with timber identification and systematic wood anatomy, with particular reference to family classification. There is little doubt that this awakened interest in anatomy can be directly correlated with the growth and development of the International Association of Wood Anatomists, which was inaugurated in 1930 at Cambridge on the occasion of the Fifth International Botanical Congress and formally constituted at Paris in 1931. On 1st July, 1938, the Association membership consisted of 113 wood anatomists representing 31 different countries. Both the Association and the science of wood anatomy owe much to the efforts of Professor S. J. Record of the Yale School of Forestry who, till June, 1938, was the Secretary-Treasurer of the organization.

In 1934 Professor Record (23) pointed out that an organization such as the International Association of Wood Anatomists, which has developed means for the exchange of ideas and material, must, by world-wide co-operative effort, have a new and powerful influence on taxonomy. Yet, till recently, it was apparent that the results of wood anatomical research were not "getting across" to more than a few systematic botanists. That this situation will be remedied seems probable as a result of the formation in Great Britain of "The Association for the Study of Systematics in Relation to General Biology." Wood anatomy has been considered as one of the branches of science included under general biology, and the present Secretary-Treasurer of the I.A.W.A.—Dr. L. Chalk of the Imperial Forestry Institute, Oxford—has been asked to serve as a co-opted member on the Committee of Comparative Systematics. This Committee is preparing lists of modern monographs of taxonomic interest, and it is proposed to issue a list of papers on systematic wood anatomy as a supplement to the list on botanical

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literature. It is hopeful, therefore, that the science of wood anatomy will have, in the future, a sympathetic hearing and an even better chance of proving its value in taxonomy.

At this stage, it might well be asked what evidence is there to support the claim that the wood anatomist can materially assist the taxonomist, especially since the anatomical approach is not a new departure. Radlkofer, in 1875, applied the anatomical method to the investigation of stem and leaf, and indicated the value of using anatomical characters in botanical classification. Solereder, a pupil of Radlkofer, published in 1898 a two-volume work dealing with the Systematic Anatomy of the Dicotyledons (25). What, then, has the anatomist of to-day to contribute that will influence the botanist to give due consideration to his findings? The answer is that to-day the anatomist has a very much greater and wider knowledge of the timbers of the world, and has learnt the value of certain anatomical features in the identification and classification of these woods. The work of the earlier botanists was weakest in their descriptions of woods, since it was difficult to obtain material for investigation, and methods of technique had not been standardized. Too many descriptions of wood structure were based on one, or at the most two, small samples of any one species, and these samples were in most cases from small branches. No allowance was made for possible variation within a species, and so the earlier work, although indicating distinct possibilities, failed to place the science of wood anatomy on a sound foundation. However, as the result of the intensive research of recent years, methods of technique have been developed and standardized, standards for terms and definitions drawn up (14), and the diagnostic value of the various anatomical features fully investigated. The woods of the different countries of the world have been investigated by numerous workers, and an excellent picture of the anatomical features and variations for particular botanical groups (families) has been recorded. The greater part of this work has been carried out by members of the International Association of Wood Anatomists and under the auspices of this body. It has been possible for members to obtain authentic samples of the woods of any particular family or group in which they are particularly interested, by exchange with other members or through the central clearing house of the Yale School of Forestry, where some 36,000 woods from all parts of the world have been collected under the guidance of Professor S. J. Record.

It must be understood from the outset that the anatomist has no desire to devise classifications based on anatomical features alone. He realizes that the structure of the wood is more conservative than that of the flower or the fruit, and would prefer to accept the nomenclature and classification of the botanist. Unfortunately the botanical classification does not always agree with results of anatomical investigations, and in such circumstances the anatomist wishes to be certain where the error lies. Is he, for example, to conclude that wood structure is after all extremely inconsistent, in spite of all the recent work stressing the reliability of certain characters, or is he to think with Hutchinson (15) that "the delimitation of families, of genera, and of species is sometimes very much a matter of taste and personal idiosyncrasy?" Professor Record has many times been the disbelieving anatomist, and his opinion (24) of the procedure that should be followed may be appropriately

quoted here. "He (the anatomist) may conclude that a species has been referred to the wrong genus or a genus to the wrong family or that there is something unnatural about the arrangement. His task then is not only to call attention to apparent error but also to indicate how it can be corrected. Here is opportunity for closer co-operation between anatomists, taxonomists, and all others who are interested in the relationship of plants. The ordinary systematic botanist is too often content to go his way alone ignoring or not realizing the help that is his for the asking. We must seek out those who are willing to work with us and maintain their interest and respect by the excellence of our suggestions." Some of the many examples that may be quoted to illustrate this point are given below.

In 1924, Record (23) stated that he could not understand why a certain Cuban timber was named *Copaifera hymenaefolia,* since the wood was very different from other species of that genus. Three systematists, however, assured him that the species was properly placed. However, some time later when visiting the New York Botanical Gardens, he was shown a manuscript in which the authors had referred this particular species to a new genus, thus proving that the doubts of the anatomist had been well founded. For some other instances of the way in which a knowledge of anatomy assists in clarifying points of classification, I will confine myself to several Australian examples of which I have had personal experience.

(*a*) Taxonomically, the Australian genus *Flindersia* has been referred both to the Meliaceae (Bentham and Hooker provisional classification, Hutchinson) and the Rutaceae (Engler and Gilg). In a letter to Professor Record, Mr. C. T. White, Government Botanist, Brisbane, wrote as follows:—"The members of the genus *Flindersia* seem to me to constitute a very natural group, and I do not think they can be divided into separate genera. On floral characters I should say the genus is better placed in the Rutaceae than in the Meliaceae, but would favour the formation of a separate family, 'Flindersiaceae' to receive them."* A study of the woods of the various members of this genus makes it apparent that the genus is out of place in the Meliaceae, yet the general appearance and wood structure of some of the species are not typical of the Rutaceae. While these divergences in structure are not of such a nature as to render it unlikely that the genus does not belong to the Rutaceae, it does appear that the suggestion of C. T. White, i.e., the formation of a separate family, can be supported on anatomical grounds. Full details of the structure of the woods of the genus *Flindersia* have been published elsewhere (4).

(*b*) A study of the wood anatomy of various species of Australian Cunoniaceae (5) has indicated that, on anatomical grounds, it is possible to divide the family into two groups:—

(i) Woods with opposite to scalariform intervascular pitting; conspicuous distinctly bordered fibre pits; definite tendency to scalariform arrangement of ray-vessel pits and to scalariform perforation plates (*Ackama, Anodopetalum, Callicoma, Ceratopetalum, Cunonia, Pancheria, Platylophus, Spiraeopsis, Weinmannia.*

* **Published in *Tropical Woods* No. 25 as a footnote to an article by Welch.**

(ii) Woods with alternate to opposite intervascular pitting; small bordered or distinctly bordered fibre pits; ray vessel pitting less tendency to scalariform arrangement; perforation plates greater tendency to be "predominantly simple" (*Geissois, Schizomeria*).

The point of interest to this discussion is that there has always been some confusion botanically as to whether various Australian species belong to the genus *Geissois* or the genus *Weinmannia*. In the accepted botanical classification, several species have been placed in the former genus, and at least one important forest species in the latter genus, namely, *Weinmannia lachnocarpa* F.v.M.

On anatomical grounds, the various Australian species whether classed as *Geissois* or *Weinmannia* fall into the second of the groups listed above. Examination of various species of the genus *Weinmannia* from South America, Java, Madagascar, and New Zealand, shows that anatomically they must fall into the first of the two groups listed above. It seems apparent, therefore, that the Australian species in question should be all referred to the genus *Geissois*, and for the particular species mentioned, the classification of J. H. Maiden (18), namely, *Geissois lachnocarpa* J.H.M., must be accepted.

(*c*) In his study of the comparative anatomy of the woods of the Meliaceae, Kribs (17) has pointed out the botanical confusion between the two genera *Aphanamixis* and *Amoora*. He has, therefore, listed the anatomical differences found as follows:—

Aphanamixis.	*Amoora.*
Wood parenchyma numerous in continuous tangential lines, 4-6 per mm.	Wood parenchyma scarce, not visible with lens; occurs diffuse as scattered cells.
Rays 1-2 cells wide, mostly uniseriate.	Rays 1-3 cells wide, mostly 2-3 cells.

In the investigation of the wood structure of the Australian species of this family (6), it was found that the species referred to as *Amoora nitidula* agreed anatomically with those of the genus *Aphanamixis*. It is therefore suggested that the botanical classification should be reconsidered and that it should be referred to as *Aphanamixis nitidula*.

The examples quoted have been encountered in the routine examination of the more important Australian timbers, and it seems probable that, as the investigation proceeds and the timbers of additional families studied, further evidence on the classification of various Australian species will be forthcoming.

The internal arrangement of families has often been the subject of much botanical controversy, and in many such cases the anatomy of the wood has been investigated in order to clarify where possible the grouping of the genera. One excellent example of the value of such work is given by Kribs (17), who used both wood anatomy and floral morphology in studying the internal relationships of the Meliaceae. As a result, he suggested a number of logical re-arrangements. Many other workers have studied wood anatomy in order to obtain further insight into the classification of genera within the family being investigated (Chattaway, the Sterculiaceae (3), Diehl, the Lecythidaceae (9), Garratt, the Monimiaceae (13) and the Myristicaceae (11, 12), Marco, the Rhizophoraceae (19), McLaughlin, the Magnoliales (20), Peirce,

the Cupressaceae (22) and the Taxodiaceae (21), Webber, the Malvaceae (27)). In all these cases some definite suggestions have been forthcoming regarding the grouping of genera, the position of one or more species, &c. In general, it is found that the results of anatomical studies support the ideas of one systematic botanist. In these cases, it should be immediately apparent that such evidence should be given due weight and the classification of that particular systematist officially adopted.

Garratt, as a result of his investigations of the anatomy of the Myristicaceae and related families (11, 12), stated that the anatomical features of the families under consideration lent definite support to the action of those botanists who placed this family close to the Lauraceae; Garratt also investigated the anatomy of the Monimiaceae (13), and his results tended to corroborate Hutchinson's inclusion of the family in the order Laurales. McLaughlin (20), on the results of anatomical studies of the Magnoliales, suggested a number of alterations and re-arrangements to bring about a more natural classification, since the order Magnoliales, as proposed by Hutchinson (16), represented such a heterogeneous grouping.

Of special interest to Australian forest botany is the work of Dr. Chattaway (3) on the Sterculiaceae. In the first place, her investigation of the wood structure of the Australian species usually referred to the genus *Tarrietia,* supports the conclusion of Edlin (10), who on botanical grounds states that there are no representatives of this genus in Australia and refers the Australian species back to the genus *Argyrodendron* of F. von Mueller. Dr. Chattaway states that the Australian species are quite distinct anatomically from other species of *Tarrietia* examined. In this case the taxonomist and the anatomist are in definite agreement, and the new classification should be generally accepted. The second point of interest in the work on the Sterculiaceae is that on anatomical grounds it is suggested that the genus *Brachychiton* should again be sunk in *Sterculia,* and the genus *Sterculia* subdivided into two sub-genera.

Chalk (2) has investigated the phylogenetic value of certain anatomical features of dicotyledenous woods, and has found that on the whole the grouping of genera into families is supported by the anatomy of wood. On the other hand, in the relationships between families, and in the grouping of families into orders, the parallel between anatomy and taxonomy often disappears altogether. He suggests that this is perhaps accounted for by the fact that for the taxonomist it is the family that counts, and that orders are often very difficult to define and of little practical importance. It is little wonder, therefore, that the anatomist is often consulted by the taxonomist as to the probable affinities of doubtful families.

The study of anatomy has shown certain lines of specialization or trends of evolution in structural features, and these evolutionary tendencies should be of some aid in phylogeny. Tippo (26), who has studied the comparative anatomy of the Moraceae and related families, has summarized the lines of structural evolution in wood. He has pointed out that in general the evolution of the flower has been correlated with the evolutionary development of anatomical structures, and that, after the re-arrangement of certain questionable groups, the classification of the taxonomist and the phylogenetic scheme of the anatomist show surprising agreement. The anatomist can, in Tippo's opinion.

make definite contributions to problems of phylogeny, provided he uses systems built on the basis of floral morphology as a background for his work, and provided also he proceeds with due caution because of parallel evolution in certain stem structures. Tippo also suggests that a further service which the anatomist may render the phylogenist is in the establishment of the proper sequence of groups.

When it finally comes to distinguishing between closely related species, the anatomist finds that distinctions in anatomical features are not clearly marked or are of such a nature that they are useless without statistical analysis. In many cases, of course, reliable specific distinguishing features can be found, but it is always well for the anatomist to realize that his idea of what constitutes a species may differ considerably from that of the botanist. He may consider many of the so-called species as nothing more than varieties or forms. Record (23) gives an excellent example of this. The study of numerous woods of the genus *Calophyllum* in the Yale collection failed to reveal any basis for specific distinctions. At Record's suggestion, the herbarium material was examined by P. C. Standley, botanist of the Field Museum of Chicago. The result was that four presumably distinct species were reduced to three varieties of a single species.

The question of specific distinctions is of vital interest in Australia, where so many of our commercial timbers are derived from the one genus, namely the genus *Eucalyptus.* It is often extremely important that a timber of this genus be identified correctly, and the wood anatomist does not have an easy time making this identification. In the work on the timbers of this genus, a thorough investigation of the various anatomical features has been made, and keys for identification based on the study of large numbers of samples of the different species developed (7, 8). It seems improbable that any exact classification can be made within this genus on anatomical evidence alone. At the most, a number of fairly well-defined groups can be separated. For identification of the timbers, one has to rely on additional features such as colour, density, burning splinter test, and the results of definite chemical tests. However, it is of interest to record that Blakely's classification (1) based on floral morphology is supported fairly closely by anatomical characteristics.

One further point must be made. The Division of Forest Products has made, and is still making, a collection of Australian forest species, a collection which at the present covers over 4,000 different trees. The wood anatomist must rely on the field collector to secure botanical material from the same tree as that from which the wood sample is taken, so that some definite name can be given to the wood. Is it not logical that the reverse step should also operate, that is, that the field botanist should always collect a wood sample from the same tree from which he is obtaining herbarium material? Wood samples should be filed along with the herbarium material, and, where possible, thin-mounted sections of the wood should be available for microscopic examination. If such a policy were adopted, it would be a simple matter for the botanist and the anatomist to consult over the classification of some doubtful species. Therefore, it is my plea, as a wood anatomist, that in the future the field botanist where possible obtain representative wood samples from all species collected. It is also my plea that more notice be accorded the efforts of the wood anatomists to straighten out some of the faulty classifications of certain botanists.

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Improved Pastures in the Clare District, South Australia—Investigation to Determine Suitable Introduced Species for Use in that Area.

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The work reported in this article was commenced as an Animal Nutrition project, but, with the initiation of Weeds Investigations as at present constituted in Canberra, the investigation was continued as a joint study by the officers of the two Divisions.—Ed.

Summary.

A species trial was carried out at Anama Station, near Clare, South Australia, over the three-year period 1935 to 1937, to determine the most productive pasture mixture for use in that area and the best mixture for use in competition with Cape tulip.

It was found that Wimmera rye-grass was the most productive grass of those used and also the most severe in competition with associated plants and weeds. In the third season, however, higher yields of total herbage were obtained from the *Phalaris* and perennial rye-grass swards established with the early Dwalganup strain of subterranean clover, than from the Wimmera rye-grass plots. It is doubtful whether perennial rye-grass or mid-season Mt. Barker subterranean clover will persist at Anama Station.

The seeds mixture recommended for use in this habitat is: *Phalaris tuberosa*, 3 lb., early subterranean clover 5 lb. per acre. Pastures so established have given a high level of production of total herbage. No information is available as yet to suggest that the establishment of sown pastures will lead to the control of Cape tulip on infested country, although this must be considered a possibility.

1. Introduction.

In 1934 the Division of Animal Nutrition, Council for Scientific and Industrial Research, became interested in the question of improving the pastures in the stud sheep-raising country near Clare, and in the effects of such improvement on the general health and wool production of sheep grazed on them. The property chosen for the work, Anama Station (Central Bungaree), the property of the Anama Pastoral Company, is situated some 10 miles north of Clare and is typical of a large section of country in that part of South Australia.

The problem of pasture improvement in parts of the Clare district is complicated by the presence of Cape tulip, *Homeria collina* Vent. var. *aurantiaca*, Sweet., a poisonous weed causing death when ingested by animals. Hungry stock and stock unaccustomed to its presence are often affected, but locally raised sheep avoid it and also avoid pastures in which Cape tulip is prominent. As a consequence, the actual carrying-capacity level of the pastures is reduced by its presence. This was the position on Anama Station on areas that had been grazed for many years as natural pastures, and it was obvious that before pasture improvement work, involving the introduction and establishment of suitable species, could be undertaken on a large scale, knowledge of the best method of control and eradication of this weed was necessary.

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Experiments with weed-killers were commenced, and a pasture species trial was laid down to determine the most satisfactory species for use in pasture improvement work in the area near Clare, and also the most useful species for plant competition studies with Cape tulip. The results obtained in the first three years of the species trial are reported in this paper.

2. Soil, Climate, and Existing Pastures.

The soils of the area belong to the group of red-brown earths described by Prescott (1) and are fertile sandy and clay loams overlying clay. The general topography of the country is undulating or hilly, and cultivation is sometimes hindered or prevented in the higher parts by outcrops of stone or by a certain amount of loose stone in the soil itself.

The climate is of the Mediterranean type. Effective rainfall occurs over a period of 6.0 to 7.5 months of the year, commencing in April (2). The average annual rainfall is 20.44 inches at Anama Station. The monthly rainfall for the years 1935, 1936, and 1937, and the means over a period of 18 years, are shown in Table 1.

Table 1.—Showing the Total Monthly Rainfall at Anama Station, Clare, South Australia, for the Years 1935, 1936, and 1937, and the Means over an 18-year Period.

Year.	Jan.	Feb.	Mar.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Total Inches.
1935 ..	213	..	198	215	176	193	113	288	138	305	..	65	19·04
1936 ..	140	96	..	161	209	161	263	226	67	161	53	165	17·02
1937 ..	234	51	77	211	217	183	170	450	412	22	128	217	24·26
Mean for 18 years	82	74	68	133	260	248	228	292	240	158	111	150	20·44

Anama Station is situated within an area of *Eucalyptus odorata* savannah woodland (3). The natural pastures are well suited to livestock husbandry. *Danthonia* and *Stipa* species are important perennial grasses, but introduced annual grasses such as *Festuca myuros* (silver grass), *Bromus hordeaceus* (soft brome grass), *Hordeum murinum* (barley grass), and *Avena fatua* (wild oats), and annual legumes such as *Medicago denticulata* (burr medic), *Trifolium glomeratum* (cluster clover), and *T. tomentosum* (woolly clover), provide the bulk of the grazing in the spring. Miscellaneous species including *Erodium botrys, Hypochoeris radicata, Bulbine bulbosa,* and *Lomandra dura* are common, and Cape tulip is a prominent constituent in many places.

3. Experimental Procedure.

Three grasses, *Phalaris tuberosa*, perennial rye-grass, and Wimmera rye-grass, were selected for inclusion in the trial, and each was sown with mid-season (Mt. Barker) and early (Dwalganup) subterranean clover to give six treatments in all. The clovers were sown at the rate of 5 lb. per acre, *Phalaris* 4 lb., and the rye-grasses at the rate of 6 lb.

per acre of seed. The area chosen had been well fallowed, and superphosphate at the rate of 2 cwt. per acre was drilled in prior to sowing. On 15th May, 1935, the seeds mixtures were sown and covered lightly by raking. The plots used measured 50 x 20 links or 1/100 acre in area, and the treatments were laid out as four randomized blocks. The area was top-dressed in the autumn of 1936 and 1937 with superphosphate at the rate of 1½ cwt. per acre.

The method of yield sampling adopted involved the collection of two samples, each 12½ square links in area, from each plot, at maturity in the year of establishment and on three occasions during the growing period in subsequent years. The area was grazed by sheep immediately after each sampling. The herbage from each plot was bulked and weighed, and, in the laboratory, subsamples were removed for separation into the following categories:—

Grass—material of the particular species sown.
Subterranean clover.
Miscellaneous species—annual grasses, legumes, *Erodium*, &c.
Inert material—dry straw, sticks, &c.

Oven-dry weights of the bulk and separated samples were recorded, and the actual yields of the sown and miscellaneous species on each plot were calculated after deducting the weights of inert material present.

4. Results.

1. *Yield and Effect of Grass Species.*

The summarized information concerning the comparative yield of the three grass species and their effects on the other constituents of the swards, is presented in Tables 2 and 3.

TABLE 2.—SHOWING THE YIELDS OF SOWN GRASS SPECIES AND OF TOTAL HERBAGE (MEANS OF EIGHT REPLICATES) WITH THE THREE GRASS TREATMENTS, OVER 3 YEARS, EXPRESSED IN CWT. PER ACRE.

Yield Of / With	Sown Grasses.				Total Herbage.			
	Phalaris.	Per. Rye.	Wimmera.	S.E.	*Phalaris.*	Per. Rye.	Wimmera.	S.E.
Year 1935	15·13	27·72	39·58	±2·90	15·13	27·72	39·58	±2·90
Year 1936	9·82	6·60	22·32	±0·85	26·99	15·07	22·72	±1·60
Year 1937	11·95	11·32	21·14	±1·27	42·85	38·38	28·69	±2·86

TABLE 3.—SHOWING THE YIELDS OF SUBTERRANEAN CLOVER (TWO STRAINS) AND OF MISCELLANEOUS SPECIES (MEANS OF EIGHT REPLICATES) WITH THE THREE GRASS TREATMENTS, OVER TWO YEARS, EXPRESSED IN CWT. PER ACRE.

Yield Of / With	Subterranean Clover—Two Strains.				Miscellaneous Species.			
	Phalaris.	Per. Rye.	Wimmera.	S.E.	*Phalaris.*	Per. Rye.	Wimmera.	S.E.
Year 1936	12·83	6·36	0·21	±1·43	4·34	2·11	0·20	±0·41
Year 1937	12·41	8·97	2·29	±0·37	18·49	18·07	5·26	±1·69

The three grasses were the only constituents in the samples collected from the swards in 1935, as the small quantity of subterranean clover, the only other species occurring, had matured and broken up prior to sampling.

From Table 2 it will be seen that the total yield of Wimmera rye-grass was significantly greater than the yield of the other grasses in each year. In the seedling year perennial rye-grass outyielded *Phalaris,* and in the second year *Phalaris* outyielded perennial rye-grass, but in 1937 the yields of these two species did not differ significantly from one another.

The differences in the yields of subterranean clover with the three grass species were very definite (Table 3) both in 1936 and 1937. The mean yield of the two strains over these two years was only 1.25 cwt. per acre in the presence of Wimmera rye-grass, compared with 7.67 cwt. and 12.62 cwt. per acre when grown in association with perennial rye-grass and *Phalaris* respectively.

The effect of Wimmera rye-grass in suppressing the growth of miscellaneous species is shown in Table 3. In the third year of the swards the yield of these species was only 5 cwt. per acre in the presence of Wimmera rye-grass, but was over three times as great (18 cwt. per acre) on the swards sown with *Phalaris* or perennial rye-grass.

The greatest quantity of total dry matter was produced on the *Phalaris* and perennial rye-grass swards in the third season. There were no significant differences in yield of herbage on the three grass treatments over the three years.

2. *Yield and Effect of Subterranean Clover Strains.*

Tables 4A and 4B show the yields of the two strains of subterranean clover over all grass treatments, and the differential effect of the two strains on the yields of the other species groups.

TABLES 4A AND 4B.—SHOWING THE YIELDS OBTAINED WITH THE TWO STRAINS OF SUBTERRANEAN CLOVER (MT. BARKER AND DWALGANUP), OVER THREE YEARS, EXPRESSED IN CWT. PER ACRE (MEANS OF TWELVE REPLICATES).

TABLE 4A.—YIELDS OF ALL SOWN GRASSES AND OF SUBTERRANEAN CLOVER.

Yield Of	All Sown Grasses.			Subterranean Clover.		
Yield With	Mt. Barker.	Dwalganup.	S.E.	Mt. Barker.	Dwalganup.	S.E.
Year 1935 ..	28·67	26·28	± 2·37	..	..	..
Year 1936 ..	14·28	11·54	± 0·70	7·89	5·04	± 1·17
Year 1937 ..	16·15	13·47	± 1·03	4·40	11·38	± 0·31

TABLE 4B.—YIELDS OF MISCELLANEOUS SPECIES AND OF TOTAL HERBAGE.

Yield Of	Miscellaneous Species.			Total Herbage.		
Yield With	Mt. Barker.	Dwalganup.	S.E.	Mt. Barker.	Dwalganup.	S.E.
Year 1935 ..	..	..	..	28·67	26·28	± 2·37
Year 1936 ..	2·47	1·96	± 0·33	24·65	18·53	± 1·30
Year 1937 ..	14·95	12·92	± 1·38	35·51	37·76	± 2·11

In 1936, the year following establishment of the swards, the recorded mean yield of the Mt. Barker strain was 2.8 cwt. per acre greater than that of the Dwalganup strain, but the difference was not significant. In the third year of the trial, the position had changed, the early strain significantly outyielding the midseason by 7 cwt. per acre (Table 4A).

The mean yield of all sown grasses on the midseason clover swards was slightly greater than that on swards of the early strain, but only in 1936 was the difference significant, and then it amounted only to 2.74 cwt. per acre (Table 4A).

Subterranean clover strain had no significant effect on the mean yield of miscellaneous species over all grass treatments (Table 4B).

The slightly greater yield of each species group in 1936, in the swards sown with the midseason subterranean clover, gave a total yield of herbage significantly greater than that obtained from the swards sown with the early strain. This difference amounted to 6 cwt. per acre. In 1937, owing to the superior yield of the early strain itself, the total yields of swards sown with the two strains were of the same order (Table 4B).

5. Discussion.

The investigation reported in this paper has yielded information on the productivity of the three grasses and the two subterranean clover strains used during the first three years of establishment. Some information has been obtained also on the inter-relationships of the grasses and clover strains in pasture swards and their effects on the establishment and productivity of miscellaneous species or weeds.

The results show that Wimmera rye-grass outyielded *Phalaris tuberosa* and perennial rye-grass in terms of actual yields of sown grasses, in each of the three years. In the seedling year, perennial rye-grass tended to outyield *Phalaris*, the reverse was true in the second year, and in the third year the yields of these two grasses were practically equal. Observation showed, however, that the plants of perennial rye-grass in the third year were small, tufted, and well separated, and the production period more restricted than in *Phalaris*. This is not regarded as a perennial rye-grass habitat (2). Although no data were obtained on the relative yields of clover strains in the seedling year, observation showed that the midseason variety yielded more heavily than the early. In the following season there was no significant difference between yields of clover strains over all treatments, but in the third year the early strain definitely out-yielded the midseason. Trumble (2) has shown that the midseason (Mt. Barker) strain of subterranean clover requires a period of effective rainfall (the period when $R/E > 0.3$) of 7.5 months or more, while the early strain (Dwalganup) is successful in districts with an effective rainfall period of over 6.0 months. Anama Station occupies an area where the period of effective rainfall exceeds 6.0 months but is usually less than 7.5 months, and it is unlikely that the midseason type will persist in a high state of productivity in that area.

The results obtained provide interesting information on the effects of the sown grasses on the associated clover strains and miscellaneous species. In 1936, the second season, the highest clover yields were

obtained on the *Phalaris* plots and the lowest on the Wimmera rye-grass swards. Perennial rye-grass was intermediate in effect. Apparently the yield of clover in this year was influenced by the rate of establishment of the grasses in the seedling year, the vigorously growing Wimmera rye-grass almost preventing clover establishment, while perennial rye-grass was more severe in competition than *Phalaris*. In the third season, the yields of clover strains were similar on the *Phalaris* and perennial rye-grass swards but were still greatly reduced where Wimmera rye-grass was sown. The yields of miscellaneous species were influenced by the sown grasses in the same manner. It is apparent, therefore, that, of the three grasses sown and at the seed rates used, Wimmera rye-grass competes most strongly with associated plants, and perennial rye-grass is more effective in this way in the early stages than *Phalaris*, although with opening up of the perennial rye-grass stand in the second year, the competing effect of perennial rye-grass is greatly lessened. The grasses themselves were stimulated in yield in the second year when growing in association with midseason subterranean clover, as compared with their productivity on the early strain plots, but this effect was not apparent in the third season. The clover strain itself had no effect on the yield of miscellaneous species.

With regard to total yields of herbage, the Wimmera rye-grass plots were the most productive in the seedling year, the *Phalaris* and Wimmera rye-grass mixtures were more productive than perennial rye-grass in the second season, and the *Phalaris* swards and perennial rye-grass with early subterranean clover outyielded Wimmera rye-grass in the third. Over the whole three-year period, however, no significant differences in terms of total herbage yield were observed between the three grass treatments employed.

In August, 1938, observation showed that the *Phalaris tuberosa*–early subterranean clover swards were the most productive of those sown. Further weakening of the perennial rye-grass was apparent, and Wimmera rye-grass was quite unproductive at this stage, although it remained effective in preventing weed entry. This decline in the yield of Wimmera rye-grass is commonly observed over a large range of conditions, and the factors concerned are but imperfectly understood. The relatively inferior cover of clover on the mid-season subterranean clover plots further indicated the inferiority of that strain compared with the Dwalganup in this locality.

Associated with the specific investigation reported above, large scale field trials were commenced in 1936, and evidence has been obtained in this way which suggests that, with the grasses, the seed rates used in the experiment were too heavy for the conditions prevailing at Anama Station. It has been found that a seeds mixture made up of *Phalaris tuberosa*, 3 lb. per acre, and early subterranean clover, 5 lb. per acre, is suitable for the production of a highly productive pasture sward.

Wimmera rye-grass, even at low seed rates, is very aggressive in the seeding year, and to some extent prevents the satisfactory establishment of the associated clover, and consequently reduces the rate of accumulation of soil nitrogen. The production period of Wimmera rye-grass is limited in comparison with that of *Phalaris*. The addition of Wimmera rye-grass, even at the low seeding rate of ½ lb. per acre,

to the *Phalaris*–subterranean clover mixture, has been found to control miscellaneous weeds, but also to have a depressing effect on the establishment of the associated sown species. Wimmera rye-grass may prove of value in the improvement of areas which cannot be fallowed, but, where fallowing is possible and is carried out efficiently, there is no reason for its inclusion in the mixture where the actual improvement of carrying capacity is the only consideration. Laboratory work (4) has shown that Wimmera rye-grass responds immediately to enhanced soil fertility, while Cape tulip is limited in its response. The possibility of the successful use of this aggressive grass species as an active competitor with Cape tulip in the field is being studied at Anama Station.

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The Areas of Australia in which the Establishment of Exotic Plants is or Appears to be Practicable.*

By A. McTaggart, Ph.D.†

On the accompanying map, there is shown a demarcation of the boundaries of the areas of Australia in which the establishment of exotic plants is, or seems to be, practicable. For such demarcation, and for the gradation of the demarked areas, reliance has been placed upon the Meyer Ratio, which is the ratio between the mean annual precipitation and the saturation deficit, the latter being dependent upon the mean average temperature and the mean relative humidity. Isologs for a Meyer Ratio of 50, 60, 75, 100, and 150, respectively, have been plotted on the Map of the Commonwealth, as far as the meteorological data available would permit of the calculation of the ratios for definite centres. Consideration of these isologs, in relation to known success or failure in the establishment of exotics, gave rise to the following conclusion. The belt lying to seaward of the 75 Meyer Ratio isolog is one which, on the whole, definitely favours the establishment of exotic plants, while between that line and the 50 Meyer Ratio isolog their establishment becomes more and more of an uncertainty, the latter line being looked upon as approximately the limit in this respect. This pronouncement does not, however, eliminate the possibility of the occurrence of oases in the interior favouring the growth of certain exotics.

A suggested graduated scale of general favorability from the plant introduction standpoint is as follows:—

150 Meyer Ratio isolog to the Coast ..	8–10	
100 Meyer Ratio isolog to 150 M.R. Line ..	6–8	
75 Meyer Ratio isolog to 100 M.R. Line ..	4–6	
60 Meyer Ratio isolog to 75 M.R. Line ..	2–4	(a somewhat doubtful belt)
50 Meyer Ratio isolog to 60 M.R. Line ..	0–2	(a doubtful belt except perhaps for certain annuals)
Centre of Australia to 50 M.R. Line ..	0	

The maximum figure in each grade might be taken as that associated with the best soils, as, for example, such soils as the Black Earths and the Red-Brown Earths shown on Professor Prescott's soil map‡, and with the most favorable locations, such as the exterior positions within the various sub-belts, absence of rain shadow, etc.

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* A paper read at the meetings of Section K (Agriculture and Forestry) of the A.N.Z.A.A.S. Congress held at Canberra in January, 1939.

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‡ Coun. Sci. Ind. Res. (Aust.), Bull. 52. 1931.

Exotic plants found established in pastures characteristic of these sub-belts are as follow:—

150 M.R Line to the Coast	South—Rye-grasses, cocksfoot, white, subterranean, and other clovers. North—Paspalum, Kikuyu grass, Para grass, white clover on tableland, *Stylosanthes sundaica* on light coastal soils.
100 M.R. Line to 150 M.R. Line	South—*Phalaris tuberosa,* Wimmera rye-grass, lucerne, subterranean clover. North—Rhodes grass.
75 M.R. Line to 100 M.R. Line	South—Wimmera rye-grass, lucerne, burr medick. North—Rhodes grass, Wimmera rye-grass, lucerne (southern section).
60 M.R. Line to 75 M.R. Line	South—Lucerne, burr medick, *Erodium* spp. North—Rhodes grass, couch (*Cynodon dactylon*).
50 M.R. Line to 60 M.R. Line	Annuals: South—Kelch grass (*Schismus barbatus*), barley grass, burr medick, *Erodium* spp. North—Button grass (*Dactyloctenium radulans*) (also native of Australia).

The problem of supplementing these plants with other establishable exotics of economic value becomes increasingly difficult as the lower rainfall interior sub-belts are approached. The introduction of self-regenerating annuals is expected to play the leading role in attempts to improve by this means the pastures therein.

Though there is a decided limitation to the evidence available in support of the restriction of the establishment of exotic plants to the fringe belt, or belts, as plotted on the accompanying map, there are certain miscellaneous facts which might be cited in favour of the demarcation indicated.

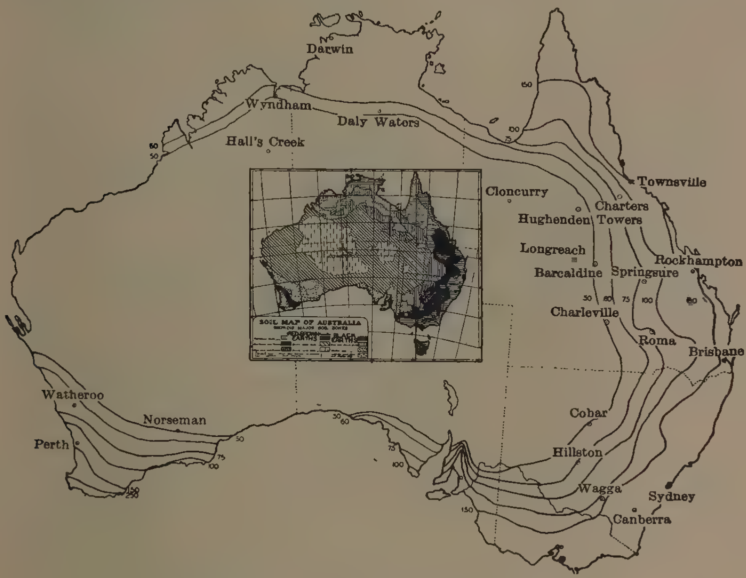
Tests of some 30 recognized dry-country grasses and other plants introduced by the Council were conducted on stations controlled by the Australian Investment Agency Ltd. These were Morstone Downs, Camooweal, (M.R. 27.8), Ord River, and Flora Valley, in the Kimberley District, and Margaret Station near Hall's Creek (M.R. 36.5). Certain species made a successful start, but were killed off eventually by the extreme heat and prolonged drought experienced there.

At Elderslie Station, near Winton (M.R. 32.1), N.W. Queensland, some 50 introduced grasses and legumes of drought-resisting reputation elsewhere were tested by Mr. J. F. Kennedy, of the Australian Estates Company. Ten did well at the beginning of the tests, but heat and drought eventually killed them off. Two lucernes ("Argentine" and "Calchaqui") of South American origin were the last to succumb.

At Barcaldine (M.R. 50.5), Central Queensland, the centre of an area of erratic rainfall, there was observed growing throughout the Mitchell grass on the black soil downs the summer annual button grass (*Dactyloctenium radulans*), a grass which is widely distributed in tropical and sub-tropical countries and is not strictly an introduced

plant, but which might be regarded as an indicator of the possible introduction of other useful self-regenerating annual grasses into this belt.

Digitaria milanjiana (a species of Woolly Finger grass introduced from South Africa) has been successfully established at Roma (M.R. 74.1), South Queensland, while *Digitaria pentzii* has been reported as being a success at Springsure (M.R. 79.8), where it is appreciated.



Map showing important Meyer Ratio Isologs.

Evidence of a different type in support of the demarcation indicated comes from New South Wales. In her thesis "A Climatic Analysis of New South Wales" (*Australian Geographer,* Nov. 1937), Elizabeth F. Lawrence, M.Sc., has shown that over a period of 36 years Cobar (M.R. 50.6), Nyngan (M.R. 52.6), Hay (M.R. 60.5), and Hillston (M.R. 61.1), experienced between them 4 to 14 humid years, 19 to 24 dry years and 3 to 8 desert years. These interior centres are, therefore, decidedly uncertain from the standpoint of possible success in the establishment of exotic plants, especially perennials.

At Walpeup, in the Mallee of North-Western Victoria, with a Meyer Ratio of approximately 65, a number of grasses, legumes, and other plants, introduced by the Council, have been tried by the Department of Agriculture of that State. Several of the more drought-resistant species have shown some indication of being successful, eventually, while one grass is now being grown on an extended scale.

At Sutherlands, South Australia, on Goyder's Line to the east of Eudunda and with a Meyer Ratio of below 50 and an average annual rainfall of 8.9 inches, upwards of 50 drought-resistant grasses, legumes, and other plants, introduced by the Council, were tried. None was

really successful. The self-regenerating introduced annuals *Schismus barbatus* (Kelch grass) and *Hordeum murinum* (Barley grass), however, succeed there.

At Merredin, Western Australia, with a Meyer Ratio of between 50 and 60, after many unsuccessful attempts to establish perennial exotics, it was concluded that establishment seems impossible there. Self-regenerating annuals, of which Barley grass (*Hordeum murinum*) and Burr medick (*Medicago denticulata*) are representative, flourish. Introduced annual species of the genus *Erodium* (Crowfoot) also grow successfully.

At Watheroo, Western Australia, with a Meyer Ratio of 65.4, four grasses introduced by the Council have shown promise of successful establishment.

Thus the successful establishment of exotic plants is governed by the factors which produce the higher Meyer Ratio values, 65 and upwards for perennials, and approaching 50 and ascending to 65 for self-regenerating annuals. On the other hand, the unsuccessful establishment of perennial exotics is determined by conditions which furnish the lower Meyer Ratio values, ranging from 27.8 to between 50 and 60 in the aforementioned evidence.

For obvious reasons, it is unnecessary here to cite any of the numerous cases of successful introduction of foreign plants into the outer subdivisions of the fringe belt of the accompanying map with their higher Meyer Ratios.

Evidence from the United States of America in support of the futility of attempting to establish exotic plant species in regions of low rainfall might be cited here. At Tucson, Southern Arizona, with a mean annual precipitation of 9.37 inches and a Meyer Ratio of 24, Griffiths, Thornber, and Wooton, after years of endeavour to introduce, under protected conditions, forage plants of various kinds, produced negative results. *Erodium cicutarium* (Alfilaria or crowfoot) and certain other aggressive annuals were the only plants that were in any way successful, and even they were crowded out by the native vegetation after a few years. It is also significant to note that here both the native and Australian saltbushes failed repeatedly to secure a hold or to make any growth of extended duration, even though they were planted on land occasionally flooded with storm water.

Plant introduction in Australia, as can be deduced from the foregoing, is restricted to a definite fringe belt, and, in general, the further one proceeds from the coast the less does this become possible. Nevertheless, the favorable rainfall, soil, and temperature conditions found in most parts of the outer subdivisions of this fringe belt afford ample scope for its further development, and the more fertile the soils therein the greater the scope. The introduction of plants of economic value on the basis of the location abroad and the study of homoclimes—in which undertaking the discovery in other countries of places with approximately similar Meyer Ratios to those obtaining here will play an important part—are ways of placing this line of useful endeavour on a more scientific footing.

Grass Types Suited to Soil Erosion Control.*

By A. McTaggart, Ph.D.†

All grass cover is important in the prevention of soil-erosion, and where such is particularly troublesome, the land should be kept in grass continuously. It is the rhizomatous or stoloniferous types, however, which are specially effective in controlling soil-erosion.

In the choice of species, within the desired types indicated above, for use where soil-erosion is rife, adaptation to the prevailing rainfall, temperature, and soil conditions has necessarily to be considered.

Before submitting the following classified list of useful and believed to be useful species, reference should be made to the most widely adaptable and perhaps most useful grass for the purpose under discussion. Couch or Bermuda grass (*Cynodon dactylon*) is a stoloniferous cosmopolitan grass which is found in many sub-tropical and tropical countries and distributed over large areas of Australia. It grows on the poorest of soils, indeed on rocky surfaces where little or no soil exists. For this reason it is particularly adapted for culture on denuded surfaces. While it shows best development in good rainfall areas, it is capable of growth under moderately low rainfall conditions. It is found in the far west of New South Wales. Indeed, isolated patches of it have been observed, it is claimed, in the heart of Australia. But from the standpoint of practical value of the grass in soil-erosion control, the coastal, sub-coastal, and sub-interior belts of Eastern, South-eastern, and South-western Australia are perhaps the only areas that can be considered. Its great variability has given rise to various strains, seed of some of which may be purchased from seedsmen. Propagation by use of sections of the stolons is also possible.

For good rainfall northern coastal areas, the following excellent soil-binding grasses may be cited:—

Paspalum dilatatum is the well-known South American grass which spreads by means of strong rhizomes and is specially adapted to moist soils where, however, frost is negligible. Seed, which is on the market, may be used, though vegetative propagation can be practised, if convenient.

Kikuyu grass (*Pennisetum clandestinum*) is a perennial East African grass which forms a dense mat by means of its stout stolons, and which is specially adapted to coastal and sub-coastal areas of good rainfall where frost is either absent or not severe and the soil is fairly fertile. Being a shy seeder, it is propagated vegetatively, which fact restricts its use somewhat. There is, however, reputed to be in Queensland a strain which produces some seed. The grass is excellent for arresting soil erosion in the areas mentioned, provided that sufficient stolons can be obtained.

* A paper read at the meetings of Section K (Agriculture and Forestry) of the A.N.Z.A.A.S. Congress held at Canberra in January, 1939.

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Carpet grass (*Axonopus compressus*) is a perennial creeping grass forming a dense turf, its trailing stems or stolons rooting at each joint. It is more adapted to sub-tropical to tropical conditions than to temperate climate soils, though it is grown in north-eastern New South Wales, and is propagated from seed.

Para grass (*Panicum barbinode*) is a coarse-growing perennial species with stout long runners or stolons which take root at the nodes. Like Carpet grass it is more adapted to tropical conditions, such as obtain in North Queensland.

Panicum trichocladum is an East African perennial grass which in moist situations forms a dense tangled growth which effectively checks soil erosion. In tropical or sub-tropical plantations, however, it may become a weed, under which circumstances it should not be used.

The rhizomatous grass *Ischaemum glaucostachyum* and the stoloniferous *Brachiaria dictyoneura*, of recent introduction from Southern Rhodesia and still under test by the Council in Queensland, are also suitable for the same purpose in northern coastal areas.

For southern coastal and sub-coastal conditions, Kentucky Blue grass (*Poa pratensis*), with its fine underground rootstocks, constitutes a useful soil-binding grass, more especially where the soil is fertile and the rainfall abundant. It is propagated readily from seed.

Water couch (*Paspalum distichum*) is also a useful soil-binder for moist soils in coastal areas both northern and southern. Propagation by use of sections of the stolons is readily carried out.

A salt-tolerating grass, introduced from the United States of America but native of Manchuria, which is suitable for soil-binding purposes under southern coastal and sub-coastal conditions, is *Calamagrostis epigeios* or Chee grass. Its strong rhizomes enable it to spread extensively under favorable conditions. It can be started from seed and multiplied by planting sections of the rhizomes.

For southern tableland and sub-interior conditions generally (20 to 30 inch rainfall), *Bromus inermis* (Awnless or Hungarian Brome grass), with its strong deeply-penetrating rhizomes and marked capacity to withstand periods of drought, is a good soil-binder. On the dry lands of western North America, it has proven its value for pasture and for holding certain types of drifting soil. Promising strains of the grass have been under test at Canberra by the Council for some years.

A blue grass recently introduced from eastern California, which spreads fairly readily and forms a very dense turf, and which may also yet prove a useful soil-binding grass in country with a rainfall of 20 inches and upwards, is Malpais Bluegrass (*Poa scabrella*). Its water requirements are low, a factor in its favour for the environment mentioned.

Other grasses, recently introduced and still under test by the Council, which have all the indications of being excellent soil-binders in the same region as that adapted to *Bromus inermis*, are the following:—

Agropyron ramosum, from the Ukraine, and *Agropyron* or *Elymus pseudoagropyron* and *Elymus angustus*, from Mongolia. All three grasses spread by means of rhizomes. The last two are particularly vigorous growers which on agricultural land might easily become

troublesome. They might, therefore, be confined, when released, to interior pastoral lands where cultivation does not obtain and where control in consequence would be unnecessary. These grasses have demonstrated their capacity to remain green under prolonged high temperatures and extended drought.

Under summer-rainfall conditions of sub-coastal and sub-interior Queensland, the Woolly Finger grasses *Digitaria pentzii* and *Digitaria valida*, introduced from South Africa, are good soil-binders because of their stoloniferous habit of growth.

For sand-drift conditions in semi-arid areas, *Elymus giganteus* (Giant Lyme grass), which originated in the sandhill regions of Central Asia, is of special interest and value. It not only arrests drifting sand but also provides grazing during the summer months. This introduced grass has already given quite promising results in sand-drifting areas in the Mallee of South Australia. Marram grass (*Ammophila arenaria*) is more adapted for drifting sand areas under higher rainfall conditions. South African Pyp grass (*Ehrharta villosa*) is also an effective sand-binder under coastal and sub-coastal conditions.

Marginal areas, especially those consisting of good soil, may be partially served by *Panicum obtusum* (Adobe or Grapevine Mesquite grass), with its long prostrate stems which root at the nodes, a grass which was introduced from Arizona, U.S.A.

Areas carrying almost all of the above-mentioned grasses are available at Black Mountain, Canberra, and at Lawes and Fitzroyvale, Queensland, for the inspection of those who may be interested. All of the grasses enumerated have more or less pastoral value, though tests with some of them are as yet incomplete. Indeed, their habits of growth, in addition to their palatability, have in most cases conferred on them distinct pasture value.

Tests on Bridge Decking.

*By R. S. T. Kingston, B.Sc., B.E.**

Recently some tests have been carried out at the Division of Forest Products, C.S.I.R., for the Country Roads Board of Victoria, to obtain information on the behaviour of unusually thin wooden bridge decking.

In view of the length of the suspension span necessary in the construction of the proposed bridge from San Remo to Newhaven, it is essential that the dead weight be as low as possible, and consequently that the decking used have a minimum possible thickness.

An important consideration in such a problem is the fact that wheels fitted with pneumatic tyres, unlike dray wheels with iron tyres, spread the load over an appreciable area. Thus, for any given total load, the maximum fibre stress in the decking is appreciably less for a pneumatic tyre than for an iron tyre.

It was decided, therefore, to carry out tests on 2 inches thick decking using a truck wheel fitted with a pneumatic tyre.

Small sections of bridge decking were constructed from planks 7½ inches x 2 inches in cross section, each being 7 ft. 3 in. long, and bearers 7½ inches x 4 inches in cross section. The bearer spacing, centre to centre, was 2 ft. 0 in., there being three spans along each plank. The decking planks were held down by two 5-inch Ewbank spikes per plank at each support. The deck was made up in two pieces, one consisting of two planks and one of three planks.

The material used for the decking appeared to be *Eucalyptus goniocalyx* (mountain grey gum) or possibly *E. globulus* (southern blue gum), the timber of these two species often being indistinguishable. The decking was tested green.

In carrying out the tests, a curved wooden loading block was placed on the truck wheel which was fitted with a 38-inch x 8-inch tyre, inflated to a pressure of 100 lb. per square inch. This transmitted the load from the head of the machine to the wheel which in turn rested in various positions on the decking. Deflections were read by means of an Ames gauge reading in 1/1,000ths of an inch, the gauge being placed beneath the decking.

Five tests were carried out. Test 1 was made on an end span and Test 2 on the centre span of the three-plank deck. Test 3 was made on the centre span and Test 5 on an end span of the two-plank deck. In all these tests the load was applied by means of the tyred wheel, the loading area, as shown by an impression on a sheet of paper, being approximately 14 inches x 6 inches at the maximum load of 10,000 lb.

In Test 4 the wheel was omitted and replaced by a loading block, 6 inches wide, reaching across the full width of one plank. The load was here applied to the centre span of the plank tested in Tests 3 and 5. This enabled the load to be increased safely above 10,000 lb. A load of 19,000 lb. was reached in this test without any sign of failure.

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The load-deflection curves of these tests are shown in Fig. 1. The curve for Test 2 was found to be practically identical with that for Test 3, for which the conditions were the same.

The deflections were as follows:—

Test.	Loading.	Span.	3 plank Deck—A. 2 plank Deck—B.	Deflection at 10,000 lb. in Inches.	Deflection at 19,000 lb. in Inches.
1	Wheel ..	End ..	A	0·16	..
2	Wheel ..	Centre ..	A	0·18	..
3	Wheel ..	Centre ..	B	0·18	..
4	Block ..	Centre ..	B	0·18	0·53
5	Wheel ..	End ..	B	0·25	..

It will be noticed that the limit of proportionality was passed at approximately 12,000 lb. weight in Test 4, whereas in the other tests this limit was in no case reached.

All deflections were measured from the intersection of the straight portion of the load—deflection curve with the axis of deflections.

The curves in the lower part of the graphs are due to initial take up. The chief cause of this was the fact that the supports were not resting firmly on the bed-plate of the machine at the commencement of the test.

It will be noticed that in no case was the deflection due to a load of 10,000 lb. greater than ¼ inch.

From the results of these tests, it appears that 2-inch decking is quite satisfactory from the point of view of both strength and stiffness.

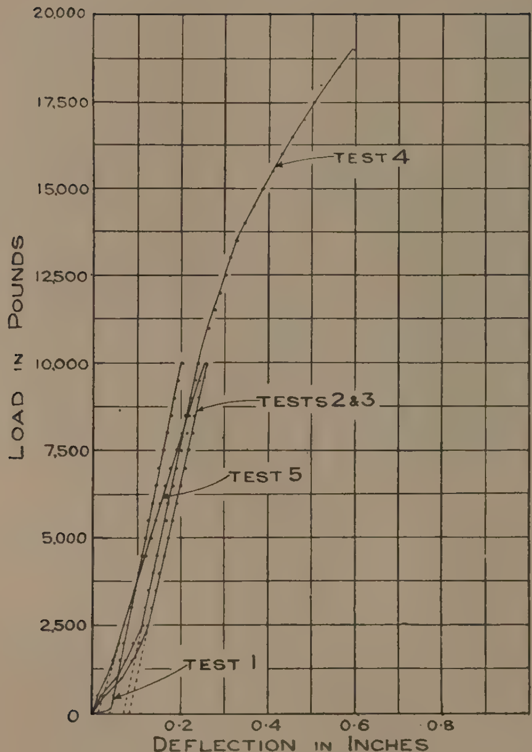

FIG. 1.—Load-deflection curves of tests made on 2-inch bridge decking.

NOTES.

Investigations on Rabbit Myxomatosis.

The work of the Council for Scientific and Industrial Research in connection with rabbit myxomatosis virus has now reached a stage at which it is possible to draw some fairly definite conclusions as to the practical value of the virus.

The history of this work is briefly as follows: Following on a suggestion by Dame Jean Macnamara, Sir Charles Martin carried out some experiments in England and advised the Council of the results. The virus having proved to be particularly virulent to rabbits, the Council brought out a supply to Australia and commenced a programme of laboratory work on the material. It has invariably been found, both in Australia and in England, that the virus is particularly deadly to rabbits, and that in a small colony it kills off the whole population.

In view of the importance of the rabbit pest throughout Australia, the Council was thus encouraged to test the possibilities of the virus in the field, and to that end work at Wardang Island was commenced.

Two series of field experiments have now been carried out. In the first series, a population of some 500 rabbits was allowed to build up in a dozen or so warrens in the enclosure of 90 acres. Rabbits caught outside the enclosure were then infected with the virus and placed inside the enclosure. Some of them were accepted by one or two of the warrens; these warrens were eventually infected and wiped out. Other warrens, however, totally escaped. The result of this first experiment thus showed that, under ordinary conditions, the disease would remain confined to warrens deliberately infected, although, at times, it might spread to one or more immediately adjacent warrens.

In the second experiment a larger population, this time of 1,000 adults and about an equal number of young, was allowed to build up inside the enclosure. The warrens numbered 33; the disease was introduced into about half of them scattered over the enclosure, and many rabbits were deliberately infected in each of these warrens. Probably only about half the population was living in warrens during the major period of the trial. The disease spread among the rabbits, and about 80 infected animals were picked up dead during each 10-day period for 100 days or more. During this time, however, breeding continued, and at the end of the experiment the number of infected rabbits decreased and some warrens lost the infection entirely. Very few warrens not deliberately infected became infected by natural spread.

Towards the end of the experiment, feed became very scarce on account of the dry weather and the large population, and hand feeding with oats had to be resorted to. Some rabbits were then artificially infected after catching them around the water troughs. As a result the death rate rose a little, but it was still insufficient to make any appreciable effect on the population.

The methods employed for disseminating the disease in this second experiment went far beyond any that could be used under natural conditions. In spite of this action and in spite of the density of the population, the end result was almost inappreciable, the death rate being almost balanced by the birth rate. The only conclusion to be drawn is that the unaided virus would prove valueless in controlling rabbit populations under natural conditions.

From observations that the investigators have made, it appears that the sick rabbit lives only about two or three days and that as soon as it becomes sick it leaves the colony and wanders aimlessly away. It therefore has little opportunity of infecting other rabbits in the colony, and probably none at all of infecting rabbits from other colonies. Thus, although the virus is very virulent to rabbits, its capacity to kill off a rabbit population is defeated by the instinctive behaviour of the animal.

Coincident with the completion of the second Wardang Island experiment, the Council received a letter from Sir Charles Martin in England, in which the following statement occurred :—

> "During the last four years I have been endeavouring to induce the virus to enhance its infectivity. From my experiments on Skokholm Island and Bull's excellent ones on Wardang Island, an insufficient infectivity is its only shortcoming. So far I have had no success. The virus has settled down to a surprisingly constant virulence and infectivity, and unless I can think of some other line to try I propose to abandon these long and rather tedious observations and merely keep the virus going in case the strain be required for experiments in Australia."

In conclusion, it is well known that some animal diseases are conveyed by insects. There is just a faint possibility that an insect affecting rabbits, e.g., the red rabbit flea, may be capable of carrying the infection from one rabbit to another. The Council thus proposes to make a full exploration of that possibility, but it should be emphasised that the chances of success along these lines are far from bright.

New Zealand Department of Scientific and Industrial Research.

Under the title of "Scientific and Industrial Research, 1927-1938", the New Zealand Department of Scientific and Industrial Research has just issued an illustrated bulletin describing the main lines of research upon which it is engaged, and the results that have been obtained, since its establishment in 1927 for the purpose of encouraging and co-ordinating scientific research and its application to the primary and secondary industries of New Zealand. Following upon an introductory section briefly describing the organization of the Department, in which is included a useful map showing the location of the various research institutes and field activities, the functions and work of the main research institutes are described with the aid of appropriate photographs and maps.

The section of the bulletin dealing with the work of the Dairy Research Institute on problems relating to the manufacture, and utilization and storage of New Zealand dairy produce is of especial interest in drawing attention to the value of research to the dairy industry. An efficient organization for co-operative work on plant research has been built up in the form of the Plant Research Bureau, and the work of its various divisions, dealing with the study and control of plant diseases, the selection and breeding of pasture and field crops, the control of insect pests, and systematic and economic botany, respectively, is described with particular reference to its economic importance.

Another section is devoted to the Wheat Research Institute, in which due prominence is given to the unique way in which wheat-growers, millers, and bakers are associated for the purpose of co-operative research on problems of the wheat industry, and the success that has been achieved in wheat-breeding—notably by the production of "Cross 7"—in improving the technique of wheat-growing and harvesting, and in assisting millers and bakers to make the best possible flour and bread, respectively. As regards the nutrition of fruit-trees, particularly important is the discovery that boron is an effective cure for corky-pit of apples, a disease which has caused serious economic loss in the past. Preliminary experiments on the gas-storage of apples to improve their keeping qualities and post-storage life, and on the production of unfermented fruit juices, are also described. The development of soil surveys in New Zealand and the work being done by the Soil Survey Division of the Department in systematically surveying and mapping the soils in New Zealand as a basis for their economic utilization, is concisely reviewed.

In the field of animal research, the most important line of investigation that has been followed by the Department is in connexion with the study of mineral deficiencies, particularly bush-sickness and related diseases. The work leading to the discovery that bush-sickness is caused by a deficiency of cobalt, and can be prevented and cured by administering minute amounts of that element, is described.

A section of the bulletin describes research on the selection and breeding of new and improved strains of *Phormium tenax* (New Zealand flax) and on the processing and utilization of *Phormium* fibre. Investigations on the composition and utilization of kauri gum are also referred to.

At the tobacco research station recently established at Motueka, work has now begun, in association with the Cawthron Institute, on tobacco seed diseases, the control of mosiac disease, and chemical investigations on tobacco soils and the quality of tobacco-leaf. A large-scale investigation on mosaic disease and the importance of various factors in its dissemination has already been completed and the results published.

The geophysical survey work of the Department, which pioneered this type of research in New Zealand, is briefly reviewed, a more detailed account being available in a separate special bulletin. Geophysical survey in New Zealand was first applied to the study of alluvial gold

occurrences, and has subsequently been applied, in conjunction with the Geological Survey, to the search for other minerals, and particularly oil.

The Department has carried out a considerable amount of work on coals and their utilization. It has recently instituted a comprehensive physical and chemical survey of the coal resources of New Zealand in order to arrive at an estimate of the total amount of coal likely to be available, and the properties of the various types with a view to determining the directions in which they can be most economically utilized.

A Radio Research Committee has recently been established; it will co-ordinate the radio research activities of the National Broadcasting Service, the Post and Telegraph Department, the Defence and Aviation Services, and the University Colleges, and will establish liaison with radio research organizations in other parts of the Empire. Three fundamental local problems are at present being studied, viz., ionospheric research, reception of overseas signals, and the propagation of radio waves over New Zealand, respectively. A report on certain aspects of the last-named project has now been published.

A Social Science Research Bureau has recently been established, under the aegis of the Department, for the purpose of co-ordinating and promoting social and economic research, and generally to fulfil similar functions to those of comparable bodies overseas. Since its establishment the Bureau has carried out a survey of the standards of life of dairy farmers, and a similar survey in certain urban communities.

The activities of the New Zealand Standards Institute, and its work in developing standardization, are briefly reviewed, and the bulletin concludes with an account of the work of the permanent scientific services, comprising the Meteorological Office, Geological Survey, Dominion Laboratory and branches, and the Observatories.

Aeronautical Research in the United States of America—A New Proposal.

According to the *New York Times*, the world's first laboratory for research work on airplane structures will be built in Sunnyvale, California, if and when Congress appropriates the sum of $6,000,000 which the National Advisory Committee for Aeronautics considers necessary for its second major research station. The new laboratory will be of such size and will have such equipment as to enable studies to be made of entire planes and not merely models.

The Committee—the operations of which have been of outstanding value to aviation since its very beginning—hopes that the money it requires will soon be forthcoming. The new proposal amounts to what is an important new departure. The first full-size wind tunnel (which was considered ridiculous by some when it was first proposed) was built by the Research Group of the Committee, and many of the major research developments that have marked aviation's brief history have followed.

The new station will be located on the West Coast, as about 50 per cent. of the big plane building is done in that locality, and the Government field is already established at Sunnyvale. Good all the year round weather in proximity to a metropolitan market were also factors in choosing the site.

The Committee's plans for its extension programme includes not only the establishment of the Sunnyvale Station with a staff of probably some 450 men, but also wider and more effective co-operation with private research centres in Universities throughout the country.

Anthelmintic Efficiency Against Immature *Haemonchus contortus*.*

General.—The efficiency of anthelmintics against adult *H. contortus* has been tested on many occasions. It has been found that carbon tetrachloride, copper sulphate solutions, and mixtures of copper sulphate with sodium arsenite or with nicotine sulphate all possessed relatively high degrees of efficiency. There was, however, no recorded information regarding the efficiency of anthelmintics against immature forms of *H. contortus*. Information of this nature is of great importance in deciding upon the interval between treatments, particularly when dealing with an acute outbreak of haemonchosis. Attention was drawn to this problem by a number of failures in treatment of outbreaks of haemonchosis.

In certain of these outbreaks, sheep were running on improved pastures at a heavy rate of stocking, and in the light of experimental results obtained, it appeared that infection was being acquired at such an extremely rapid rate that even repeated treatments failed to check mortalities. Treatment was evidently not efficient against the immature parasites which matured in the interval between administrations and thus continued the pathogenic process of infestation. As the immature forms of *H. contortus* attack the mucosa of the abomasum and suck blood vigorously, they contribute quite considerably to the development of anaemia.

Experiments.—A series of trials was carried out to test the efficiency of carbon tetrachloride, copper sulphate solutions, and mixtures of copper sulphate with sodium arsenite or with nicotine sulphate against immature *H. contortus* 10 and 15 days old.

Results indicated that copper sulphate was a very unsatisfactory anthelmintic against immature *H. contortus*. Carbon tetrachloride possessed greater efficiency, but was still not a satisfactory anthelmintic against immature worms. Mixtures of copper sulphate with sodium arsenite or nicotine sulphate were more efficient. It appeared, however, that even with these mixtures, treatment was liable to be unsuccessful in about 25 per cent. of the cases.

While egg counts indicated that a few worms had reached the egg-producing stage when fifteen days old, the majority did not reach this stage until they were about 25 to 30 days old. Treatment about

* An abstract of an article by H. McL. Gordon, B.V.Sc., an officer of the Council's McMaster Animal Health Laboratory; the full article will appear in an early issue of the *Australian Veterinary Journal*.

this time with any of the anthelmintics used would probably have been effective.

It was found that in sheep which were acquiring a number of *H. contortus* larvae daily, treatment with carbon tetrachloride at intervals of 17 days or longer was not effective in maintaining infestation at a sub-pathogenic level, but that treatment repeated at intervals of 10 days was effective. In dealing with an outbreak of haemonchosis it is therefore necessary to repeat treatment at short intervals, not exceeding 10-14 days. At the same time affected sheep should be moved from heavily contaminated pastures.

Conclusions.

1. Anthelmintics are not as efficient against immature as against mature *H. contortus*.

2. Mixtures of copper sulphate with sodium arsenite or nicotine sulphate are more efficient than carbon tetrachloride against immature *H. contortus*. Copper sulphate solution appeared to be very inefficient.

3. Because of the general inefficiency of anthelmintics against immature *H. contortus*, treatments should be repeated at about 10-14 days' intervals during severe outbreaks of haemonchosis.

4. Inefficiency of anthelmintics against the immature worms offers an explanation for apparent failures of treatment in severe outbreaks of haemonchosis in the field, particularly in those instances in which the treated flock was not moved from heavily contaminated pastures.

A New Journal—"The International Bibliography of Agricultural Economics."

The International Institute of Agriculture in Rome has now begun to publish at quarterly intervals a current bibliography dealing with agricultural economics in all its various phases. The new publication, which is based on the material received by the library of the Institute, is being compiled under the technical direction of the Librarian, Dr. S. von Frauendorfer.

The new journal will cover economic and social aspects of agriculture such as agricultural economics, agricultural policy, settlement, credit, co-operation, insurance, marketing, prices, statistics, farm organization and management, valuation, labour, accounting, rural sociology, agricultural history and geography, legislation and education and all other agricultural problems, in so far as they are considered from the economic and social point of view. Only publications of purely technical character are excluded. Titles of all publications, whether books, bulletins, pamphlets or articles in periodicals, are indicated, including all bibliographical details required for proper identification. All languages receive equal treatment, and titles in the less known languages are provided with a translation.

The bibliography, which is the only one which covers systematically the world literature on agricultural economics, is carefully classified by subjects. An author-index will be supplied at the end of each volume. The annual subscription, postage included, is 6s. 6d. or $1.60.

A copy of the first number (October, 1938) has recently become available in Australia. It consists of 137 pages.

Recent Publications of the Council.

Since the last issue of this *Journal,* the following publications of the Council have been issued :—

Bulletin No. 125.—" A Soil Survey of Part of the Kerang District, Victoria," by J. G. Baldwin, B.Agr.Sc., G. H. Burvill, B.Sc. (Agric.), and J. R. Freedman, B.Agr.Sc.

This Bulletin describes the results of a soil survey of 54,000 acres of the Kerang Irrigation District, in the Murray Valley in northern Victoria. Since this area was opened for irrigation, an increasing soil salinity has caused considerable loss of productivity, and the survey was designed to form the basis of future rehabilitation. An account of the district's climate, physiography, and vegetation is given, and then the soils of the area are described in detail, their distribution being shown on a soil map. The salt status of the soils was examined throughout the survey, and its relation to irrigation and vegetation is shown. The salt tolerance of many species of plants was studied in detail, and the range of their tolerance is defined. The present agricultural state of the district is described, and the course of its deterioration traced. It is concluded that reclamation is thoroughly practicable, and the means of improvement are outlined. The work was carried out by the Council's Division of Soils in co-operation with the Victorian Department of Agriculture.

Bulletin No. 126.—" Investigations on Chilled Beef. Part I. Microbial Contamination acquired in the Meatworks," by W. A. Empey, B.V.Sc., and W. J. Scott, B.Agr.Sc.

The work discussed, which was carried out by the Council, was made possible by the provision, by the Queensland Meat Industry Board, of laboratories and experimental cold rooms at the Brisbane Abattoir, and substantial annual grants for their maintenance.

This publication is the first of a series of three which will deal with investigations into the practices for preparing chilled beef in Australia for export, with a view to reducing the excessive microbial wastage of the beef during the voyage to Great Britain. Each will deal with one of the three main factors controlling the rate of onset of microbial spoilage of beef. The first factor is the extent and nature of the " low temperature type " contamination of the beef surfaces in the meatworks, and the present publication describes the investigations into the nature, extent, and methods of reduction of the naturally-acquired microbial contamination. The methods for the reduction of the contamination have been found to be both reliable and economically feasible.

Pamphlet No. 89.—" Needle Fusion of *Pinus* in Southern New South Wales. Second Progress Report (1937-38)," by W. V. Ludbrook, B.Agr.Sc., Ph.D.

The distribution, importance, and symptoms of the disease of *Pinus* known as needle fusion, and the earlier stages of the present investigation, were described in a previous report, which dealt with the first four years of the writer's work on this problem.

The second progress report deals mainly with the changes in percentage of diseased trees in plots of five species of *Pinus* with increasing age, with the effects of chemicals on diseased trees, and with the relative economic importance of needle fusion in certain species of *Pinus.* The cause of the disease is still unknown.

Pamphlet No. 90.—"Studies of the Physiology and Toxicology of Blowflies. I. The Development of a Synthetic Medium for Aseptic Cultivation of Larvae of *Lucilia cuprina*," by F. G. Lennox, M.Sc., A.I.C.

The object of the experiments described in this paper was to evolve a simple synthetic nutrient medium for the cultivation of blowfly larvae. A basal medium was evolved containing only yeast and sodium chloride, in addition to agar, which is added to give a suitable gel consistency. Although larvae reach full size on this medium, growth is more rapid on an enriched medium containing fresh egg-white in place of agar. The pH limits for growth on synthetic media were found to be wide, varying from below four to beyond eight or ten.

A technique is also described for the cultivation of larvae of *L. cuprina* in small, flat-walled bottles, growth being recorded without opening the cultures by photographing the larvae at a standard magnification.

Forthcoming Publications of the Council.

At the present time the following future publications of the Council are in the press:—

Bulletin No. 127.—"Radio Research Board, Report No. 14."

"1. Further Studies of Directions of Atmospherics at Toowoomba and Canberra," by H. C. Webster, Ph.D., F.Inst.P., G. H. Munro, M.Sc., A.M.I.E.E., and A. J. Higgs, B.Sc.

"2. An Aperiodic Amplifier for Investigating the Wave-Form of Atmospherics," by H. C. Webster, Ph.D., F.Inst.P.

"3. Applications of the Modulating Electrode of Television Cathode-Ray Tubes in Investigations of the Wave-Form of Atmospherics," by H. C. Webster, Ph.D., F.Inst.P.

Bulletin No. 128.—"An Investigation of the Problems of Salt Accumulation on a Mallee Soil in the Murray Valley Irrigation Area," by J. E. Thomas, B.Sc., B.Agr.Sc., B.V.Sc.

Bulletin No. .—"Investigations on Chilled Beef: Part II. Cooling and Storage in the Meatworks," by W. J. Scott, B.Agr.Sc., and J. R. Vickery, M.Sc., Ph.D.

Wanted to Buy—"Chemical Abstracts," &c.

The Council for Scientific and Industrial Research would like to buy back volumes of "Chemical Abstracts" (U.S.A.), "British Chemical Abstracts", and "Chemisches Zentralblatt". The Council would also possibly buy back numbers of other abstracting journals of a scientific nature.

Would anyone having any of the above material available for disposal please communicate with the Secretary of the Council, 314 Albert-street, East Melbourne, C.2.

T. Rider, Acting Government Printer, Melbourne.

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